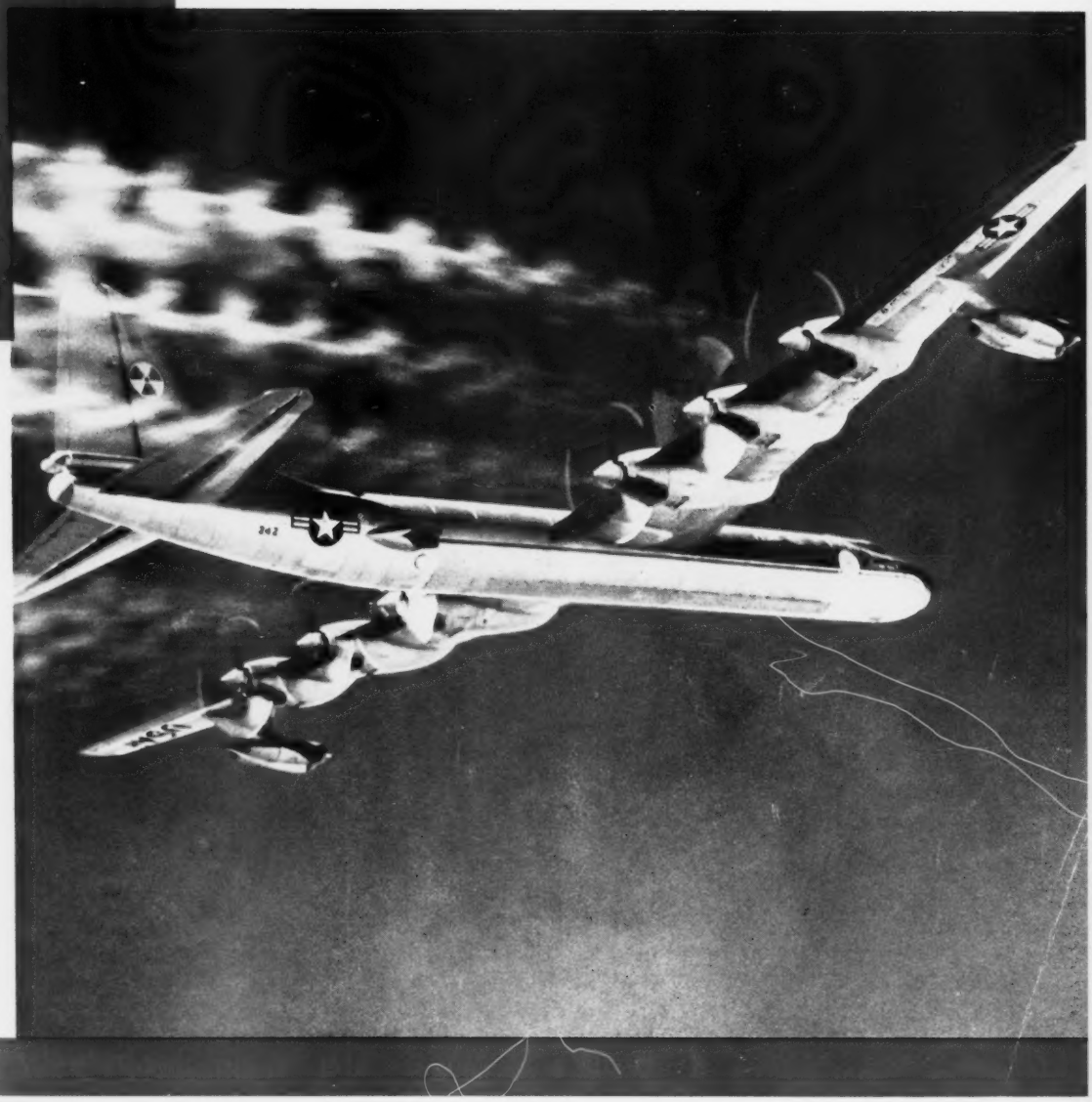
LIBRARY

Aeronautical Engineering REVIEW

INSTITUTE OF THE AERONAUTICAL SCIENCES



November, 1956

★ ***AIRCRAFT PUMPS***

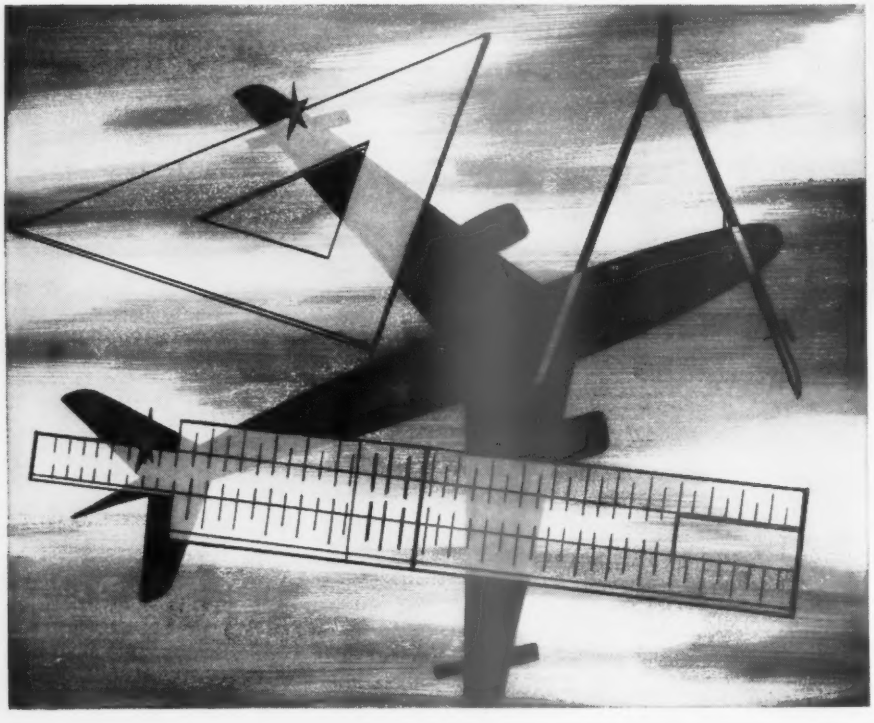
Precision-built to rigid government specifications, a broad selection among Eastern pumps offers flexibility to your choice. Modifications can be made, or custom-made units designed to suit your project. Trim in size, light in weight, Eastern Aircraft Pumps give reliable long-term service.

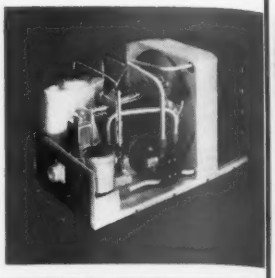
★ ***PRESSURIZATION***

Eastern pressurization units for airborne electronic equipment are available in many capacities to handle a broad range of requirements. Units consist of an air pump and motor assembly, pressure switch, check valve, tank valve, and terminal connectors. They meet government specifications and can be modified to your needs.

eliminate the "BUGS"

with Eastern aviation products





★ ***COOLING UNITS***

Hold temperatures to safe operating limits in liquid cooled electronic tubes or similiar devices. By virtue of long experience and using standard component parts, Eastern can suit your specific needs at a minimum cost for equipment.

★ ***REFRIGERATION-TYPE***

Enable specified components to be held to fairly constant temperatures by use of various types of refrigeration units. Because of the variation in methods possible, Eastern units fill every requirement where the use of a refrigeration cycle is called for.

★ *SPECIAL UNITS*

Eastern's continual research and development program keeps pace with the growing aviation industry. As new problems occur with progress in aircraft development, Eastern units are constantly developed to fill their function as planes fly higher, or faster, or with greater load capacity.

Eastern welcomes the chance to help engineers "take out the bugs" with equipment that cools, pressurizes, or pumps. From the extensive line of existing units, new adaptations, or custom-made designs, Eastern is ready to meet every challenge for equipment that handles your needs *the best today . . . better tomorrow.*

Eastern

EASTERN AVIATION PRODUCTS

INDUSTRIES, INC.
100 SKIFF ST.
HAMDEN 14, CONN.

Write for Aviation Products Catalog, Bulletin 330

Aeronautical Engineering Review

Vol. 15—No. 11 November, 1956

CONTENTS

Surface-Protection and Cooling Systems for High-Speed Flight ..... *D. J. Masson and Carl Gazley, Jr.* 46

Techniques and Problems in Testing Structures at Elevated Temperatures ..... *Lewis H. Abraham* 56

A Re-Evaluation of Some Air-Frame Thermal Problems ... *Norris F. Dow* 61

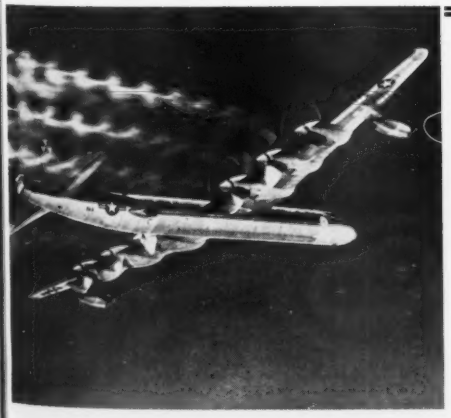
Induction System Selection ..... *Harry Drell and Thomas A. Sedgwick* 67

Flight Application of Target-Simulator Principles .. *William M. Kauffman* 76

STOL-VTOL Aircraft in the Air Mobile Army ..... *Lt. Col. Michael J. Strok, U.S. Army* 81

Operational Aspects of the SAC Transition to Jets ..... *Col. Richard E. Evans, USAF* 86

IAS News Notes 33
IAS News 35
Editorial 44
Special IAS Publications 94
Aeronautical Reviews 119
International Aeronautical Abstracts 135
Books 175
Personnel Opportunities 189
IAS Preprints 198
Index to Advertisers 200
New Products and Product Literature 203



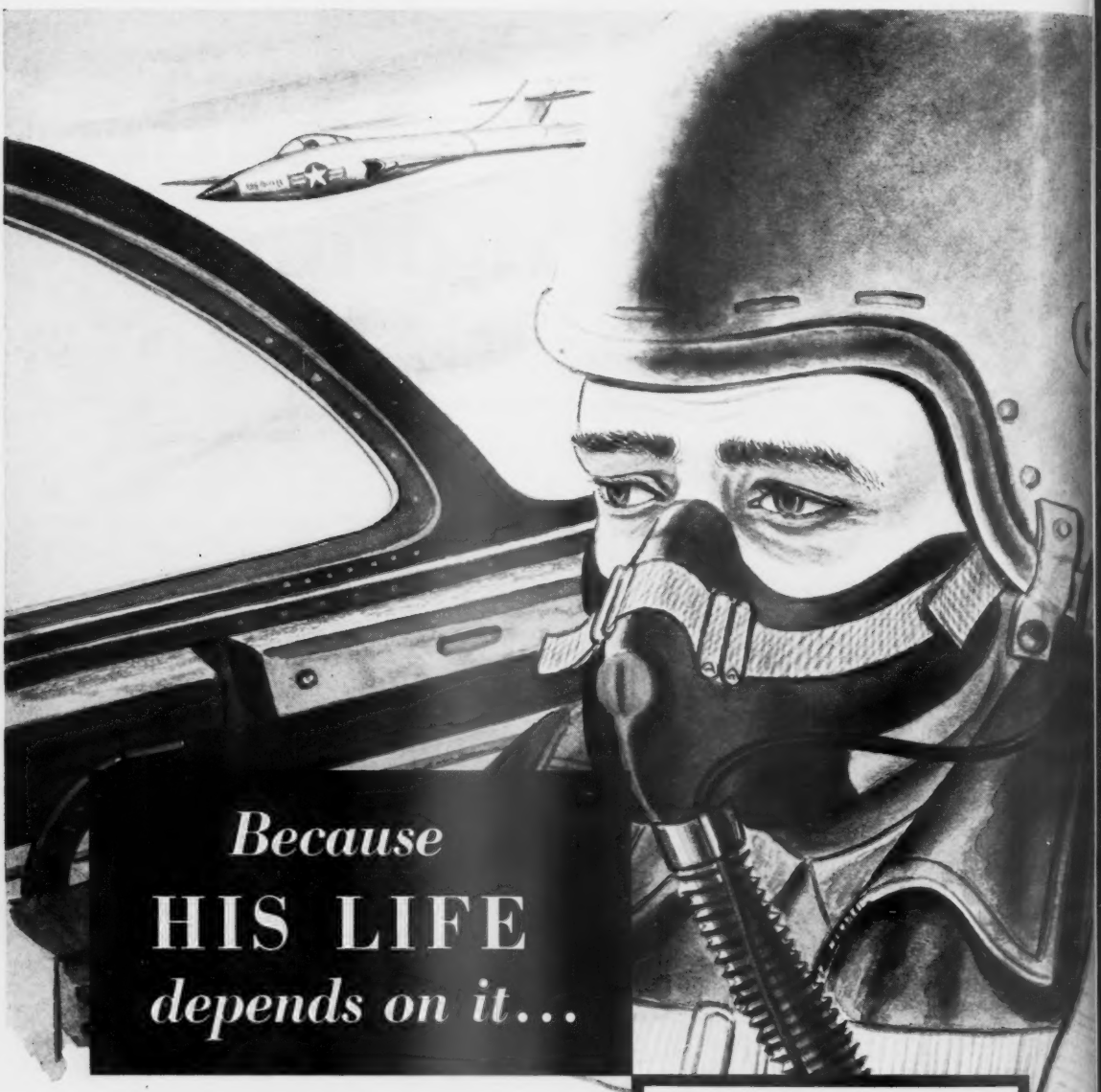
Cover—First photo of the Convair NB-36H nuclear test airplane shows the testbed at great altitude somewhere over the southwestern United States. The Ft. Worth, Tex., plant of Convair Division of General Dynamics Corporation is carrying out research leading to development of an atomic-powered airplane. The "hot" reactor does not power the NB-36H; it never is operated unless over an unpopulated area and then only to obtain data on air-borne nuclear reactor operation. Radiation effects on instruments, equipment, and air frame are measured and a wide variety of shielding possibilities checked out.

Published Monthly by the

Institute of the Aeronautical Sciences, Inc.

2 East 64th Street, New York 21, N.Y.

Western Office: 7600 Beverly Blvd., Los Angeles 36, Calif.



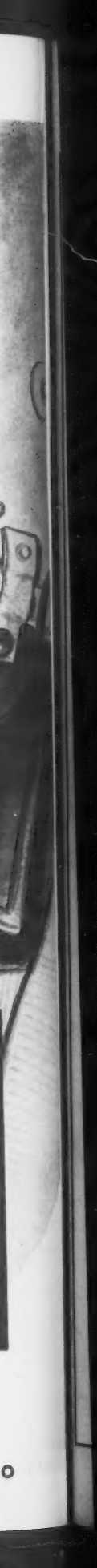
Because
HIS LIFE
depends on it...

. . . Nothing is left undone to make the Relief Valve in the fuel pump, the Safest, the most Dependable, the Lightest valve possible with today's skills and materials.

Fluid Regulators Corp. is a Major Designer and Producer of Relief Valves for jet fuel pumps.

Fluid Regulators
CORPORATION • 250 E. MAIN STREET • PAINESVILLE, OHIO

Designers and Producers of Aircraft Hydraulic and Fuel Valves.



THE
Cha
17 b
(See
able

195
sup
by
Uni
the
Cor
7.
gra
one
pre

A
Bo

DI
tab
ton
De
Cl
tri

PR
ing
19
th
Ae
m

R
so
sa
C
F
R
ar
B
M
g
U
S

I.A.S. News Notes

November 1956

THE TOPIC of this year's Wright Brothers Lecture, to be delivered at the U. S. Chamber of Commerce Building Auditorium in Washington, D. C., on December 17 by Sir Arnold Hall, will be "Comments on Some Current Aviation Topics." (See following page). Sir Arnold has advised the Institute that he will not be able to repeat the Lecture.

1957 DATES for three of the eight annual IAS Regional Student Conferences, supported by the Minta Martin Aeronautical Student Fund, have been announced by the Institute. The three will be the Northeastern Conference, with Princeton University as host, at Princeton on March 30; Indianapolis Conference, with the Indianapolis Section as host, at Purdue University on April 8; and the Detroit Conference, with the Detroit Section as host, at Wayne State University on May 7. In each of these competitions, papers will be judged in undergraduate and graduate divisions. Students are cautioned that a paper may be judged in only one conference. If a student participates in more than one conference, he must present separate papers in each.

A NEW CORPORATE MEMBER of the Institute is Allied Research Associates, Boston. Lawrence I. Levy, MIAS, is President.

DIRECTOR OF THE TRAINING CENTER for Experimental Aerodynamics, established by AGARD, of NATO, will be R. Paul Harrington, AFIAS. Dr. Harrington has been granted a two-year leave of absence from his post as Head of the Department of Aeronautical Engineering at Rensselaer Polytechnic Institute. Classes, with a select group of about 20 students representing 10 NATO countries in attendance, were scheduled to start late last month.

PROCEEDINGS of the Third National Turbine-Powered Air Transportation Meeting, in San Diego August 15-17, are now available. The bound volume contains 19 papers presented at the meeting and all discussions. Members may obtain the PROCEEDINGS for $3.50 from the Publications Department, Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, New York. The non-member price is $6.00.

RECENT LOSSES THROUGH DEATH to the Nation and to the Institute include some of the most illustrious names in aviation. The Institute was most recently saddened by the passing of LAWRENCE D. BELL, AMIAS, Founder and Board Chairman of Bell Aircraft Corporation; Professor DANIEL CLEMENS SAYRE, FIAS, Director of the Forrestal Research Center at Princeton University; SIR RICHARD FAIREY, an Honorary Fellow and Benefactor of the Institute, Founder and Executive Chairman of The Fairey Aviation Co., Ltd.; and WILLIAM E. BOEING, Sr., whose Boeing Airplane Company has been a long-time Corporate Member of the IAS. The Review's Necrology for December will record biographical data on the following: SIR RICHARD, Major RICHARD R. SHEAK, USAF, MIAS; BALDWIN M. WOODS, AFIAS; WILLIAM M. DRAKE, TMIAS; STEWART W. COGSWELL, MIAS, and SAMUEL NIEDELMAN, MIAS.

* * * *

I.A.S. News Notes (con't.)

SECTION MEETINGS CALENDAR

Nov. 7 - Texas Section: Specialist Meeting, Arlington State College Engineering Auditorium, 8 p.m. "Supersonic Wind Tunnel Testing" by R. J. Volluz.

Nov. 8 - Baltimore Section: Dinner Meeting, Aircraft Armaments, Inc., Cockeysville, Md., 6:30 p.m. "Rocket Sled Vehicles and Test Operation." (4 speakers.)

Nov. 10 - San Diego Section: Annual Fall Dance, IAS Building, 9 p.m.

Nov. 12 - Indianapolis Section: Dinner Meeting, Purdue University, West Lafayette, Ind., 6 p.m. "What's New at Purdue?" (Several speakers.)

Nov. 12 - Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Beryllium as an Aircraft Structural Material" by George A. Hoffman.

Nov. 13 - Detroit Section: Joint Dinner Meeting with American Rocket Society, Student Union Building, University of Detroit. "Prospects for Space Flight" by Norman V. Petersen.

Nov. 13 - Washington Section: Dinner Meeting, Occidental Restaurant, 6 p. m. "NACA Crash Survival Research" by I. Irving Pinkel. (IAS President Edward R Sharp, Honorary Chairman.)

Nov. 14 - Chicago Section: Dinner Meeting, Glenview NAS Officers Club Lounge, 6:30 p.m. "Absolute Capability - Key to Survival in the Thermonuclear Age" by Captain Norval R. Richardson, USN.

Nov. 14 - Columbus Section: Tour of Columbus Plant Laboratory, North American Aviation, Inc. (Hour subject to last minute scheduling.)

Nov. 15 - Dayton Section: Dinner Meeting, Levitt's Manor, 6:30 p.m. "VTO and STO Aircraft" by Frank Piasecki.

Nov. 20 - Cleveland-Akron Section: Tour of General Tire & Rubber Company, Akron, 3:45 p.m.; Dinner Meeting, University Club, Akron, 6:30 p.m. "Convertiplanes and VTOL Aircraft" by Robert J. Woods.

Nov. 20 - Hagerstown Section: Dinner Meeting, Terrace Restaurant, 7:30 p.m. "Vertical Riser - An Engineering Test Pilot Report" by Skeets Coleman.

Nov. 23 - Texas Section: Dinner Meeting, Amon Carter Field, 7 p.m. "Crusader Speed Record (Thompson Trophy Race)" by John W. Ludwig.

Nov. 27 - Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Real Gas Effects in Couette Flow" by Hans W. Liepmann.

Dec. 4 - Boston Section: Specialist Meeting, Wayland Laboratory, Raytheon Manufacturing Company, 8 p.m. "Automobile Stability and Control as Seen by the Aeronautical Engineer" by David W. Whitcomb.

NATIONAL MEETINGS CALENDAR

Nov. 26-27 International Meeting, Canadian Aeronautical Institute and the IAS, Royal York Hotel, Toronto, Ontario, Canada.

Dec. 17 Wright Brothers Lecture, U S. Chamber of Commerce Building Auditorium, Washington, D. C. "Comments of Some Current Aviation Topics" by Sir Arnold Hall.

Jan. 28-31 Twenty-Fifth Annual Meeting, Sheraton-Astor Hotel, New York, N. Y.

Mar. 14-15 Flight Propulsion Meeting, (Classified), Hotel Carter, Cleveland.

Sept. 1-16 Sixth International Aeronautical Conference, Royal Aeronautical Society and the IAS, Folkstone, England.

IAS News

A Record of People and Events of Interest to Institute Members

British Scientist to Deliver Wright Lecture

Sir Arnold Hall, FRAeS, Accepts Institute's Invitation; Will Speak in Washington, D.C., on December 17

SIR ARNOLD HALL, of England, who became Director of the Royal Aircraft Establishment in 1951 at the age of 36 and whose remarkable career in the aeronautical sciences resulted in knighthood in 1954, has accepted the Institute's invitation to deliver the Wright Brothers Lecture for 1956.

For the last year, Sir Arnold, now 41, has been Technical Director and Scientific Adviser and Consultant for the Hawker Siddeley Group Limited, London. His lecture will be heard at 3 p.m., December 17, in the auditorium of the U.S. Chamber of Commerce Building, Connecticut Avenue and H Street, N.W., Washington, D.C. The event each year attracts many leading aeronautical engineers and research scientists. All IAS members are welcome.

Sir Arnold has chosen as the subject of his lecture "Comments on Some Current Aviation Topics."

In addition to his RAeS affiliation, Sir Arnold is a Master of Arts, Honorary Associate of City and Guilds of London Institute, and a Fellow of the Royal Society. He is also a Member of the Air Safety Board and of the Aeronautical Research Council.

The 1956 Lecturer gained world recognition for his work in connection with the RAE inquiry into causes of the Comet Airliner crashes; it was under his direction that the task of nearly complete reconstruction of a crashed Comet was undertaken and cause of the accidents established.

While in high school, Sir Arnold was awarded a scholarship to Clare College, Cambridge, where he enrolled with the intention of becoming an electrical engineer. As Sir Arnold puts it, however, he was "lured into aeronautics by the brilliance of lectures given by Sir Melvill Jones, the Professor of Aviation." (Sir Bennett Melvill Jones is one of 33 Honorary Fellows of the IAS.)

At Cambridge, Sir Arnold took the mechanical science tripos and received a first-class honors degree of Bachelor of Arts with distinction in aeronautics, heat engines, applied mechanics, and theory of structures.

On graduation, Sir Arnold served for a short time at the RAE but soon returned to Cambridge, becoming a Research Fellow in Aeronautics of the Company of Armourers and Brasiers. Envisioning war, Sir Arnold returned to the RAE in 1938 as Principal Scientific Officer and worked on a variety of tasks, contributing to a 600-m.p.h. wind tunnel and in the development of bomb and gun sights.

The war over, Sir Arnold was appointed Zaharoff Professor of Aviation at the University of London and at the same time became Head of the Department of Aeronautics at the Imperial College of Science and Technology. In 1951, 6 years later, after the sudden death of the RAE Director, he was offered the position and accepted.

Sir Arnold Hall

Twelve Technical Papers Will Be Delivered at Third CAI-IAS Meeting in Toronto

The completed program for the Third Annual CAI-IAS International Meeting in Toronto, Canada, on November 26 and 27, lists the identities of authors and titles of twelve technical papers to be presented at four sessions. The conference, slated for the Royal York Hotel, will get under way at 8:30 a.m., Monday, November 26, with registration in the Convention Floor Foyer. Registration is free to IAS-CAI members; others will be charged $2.00.

Principal speaker for the meeting, who will address the assembly in the hotel's Concert Hall at 7 p.m. on the 26th, will be Clifford C. Furnas, FIAS, United States Assistant Secretary of Defense, Research and Development. Dr Furnas' topic has not been announced. IAS President Edward R. Sharp and CAI President T. E. Stephenson also will speak.

"The Guided Missile as a Systems Engineering Problem" has been listed as the topic of Simon Ramo, Executive Vice-President of The Ramo-Woodridge Corporation, who has been designated as the first American to give the W. Rupert Turnbull Lecture. Lecture Chairman will be J. C. Floyd, Vice-President—Engineering, Avro Aircraft Limited.

The four technical sessions scheduled are Test Flying, Quality Control, Electronics, and Missiles. Their chairmen, respectively, will be W. S. Longhurst, Chief of Flight Operations, Canadair Limited; H. S. Rees, Chief Aeronautical Engineer, Department of Transport; G. F. Kelk, President, George Kelk Limited; and G. D. Watson, Director of Weapons Research, Defence Research Board.

(*Continued on page 117*)

The Palm Room of the U.S. Grant Hotel provides the setting for the third NTPAT technical sessions.

▼ ▼ ▼

The Third

National Turbine-Powered Air Transportation Meeting

San Diego, Calif.

With the high standards of two preceding NTPAT meetings at Seattle to shoot at, the IAS San Diego Section did itself proud in arranging and carrying out the third of these increasingly popular national sessions. A well-balanced program of technical papers, exhibits, and a static display of the latest turbine-powered aircraft reflected the careful planning and effort put into this program by the local Section officers and committee members under the chairmanship of Earl R. Hinz.

The full report of the technical sessions has been published in a single volume of *Proceedings*. This includes the luncheon talk by Peter Masefield and the dinner address by Major Gen. Brooke E. Allen, in addition to all technical papers presented. Copies of the *Proceedings* are now available through the Institute's publications department.

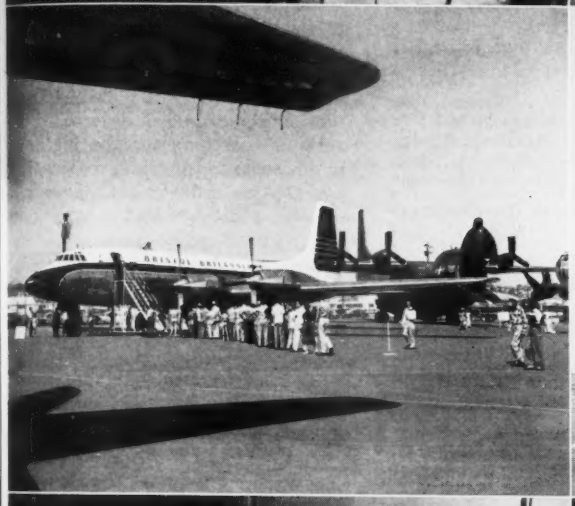
Under the expert guidance of Chairmen William Littlewood, Tom Smull, Dixon Speas, and Ralph Bayless, the technical sessions produced papers and discussions on everything from the "Introduction of Turbine Transports into Service" to the "Future Technical Trends in Air Transportation." The problems of design, testing, operation, noise—and even financing—were capably presented by such authorities as Maynard Pennell, Ivar Shogran, M. C. Haddon, J. H. Famme, Marvin Whitlock, William Del Valle, W. C. Mentzer, Dr. Paul Borsky, Alan Powell, K. M. Stevens, "Tex" Johnston, J. B. Franklin, Walter M. Sharp, George Worley, Harmer Davis, and R. L. Carter.

An experimental innovation at this year's meeting was a relatively small, but well-executed, exhibit of related aircraft and products at the Institute's San Diego building. Displays by Allison, AiResearch, Boeing, Caravelle, Convair, Fairchild, General Electric, Goodyear, Jack & Heintz, Meletron, Norden-Ketay, Rohr, Rolls-Royce, Ryan, Shell, Solar, and Western Gear added considerable interest to the meeting. Some 20,000 visitors saw the exhibition and had an opportunity to examine at close range the Lockheed C-130 "Hercules" transport, a military version of Boeing's double-decker Stratocruiser, and Bristol's "Britannia." These aircraft, together with one of the Navy's R3Y Convair flying boats, were on static display at the Convair ramp adjoining the IAS building.

The practicality of turbine-powered transportation was portrayed most realistically, perhaps, by the series of demonstration flights put on by Peter Masefield and his crew in the Bristol "Britannia." Those who were privileged to take a flight in this plane were greatly impressed by its performance characteristics and passenger comfort.

Taken as a whole, this third NTPAT meeting did much to advance the progress of our aerial transportation industry.

W.A.S.



Random shots from the third National Turbine-Powered Air Transportation Meeting.

(Top) Peter Masefield and Major Gen. Brooke E. Allen.
(Center) Bristol's "Britannia" on static display.
(Bottom) Exhibits at the IAS building claim the attention of thousands of visitors.

(Top) General Allen addressing the dinner audience.
(Center) Lockheed's C-130 turboprop transport.
(Bottom) First-day speakers' panel: Chairman William Littlewood, M. C. Haddon, Ivar Shogran, and M. L. Pennell.

▲ ▲ ▲

IAS President Predicts Challenge of Flight Will Succumb to Research and Teamwork

Head of Lewis Lab Asks Members to Utilize Fully Facilities of Institute; Says Security of United States Depends on Wisdom, Skill of Scientists, Engineers

While the challenges of flight remain many and great, they cannot stand invincible against the onslaught of learning and effort, IAS President Edward R. Sharp declared September 6 in a President's Night address before the Atlanta Section.

Urging full utilization of IAS facilities, Dr. Sharp warned Georgians and their guests:

"Whatever our goals in life, we must work hard, study constantly, seek truth and think big and then, truly, those who accept the challenge of flight will find the sky is no limit."

That secrets of the unknown will be unfolded was held out as a certainty by the Director of NACA's Lewis Flight Propulsion Laboratory, who asserted:

"We will succeed through teamwork—close teamwork between those engaged in research, design, production, military and air transport.

"We will succeed through intensified training—advanced training in all the disciplines so that the industry can move forward with confidence on all fronts.

"We will succeed by greater emphasis on advanced tools for research—greater emphasis on advanced tools for research—and, even more important, greater incentives for the bringing forth of advanced concepts.

"And we will succeed if we fully utilize the facilities of the IAS and take every opportunity to exchange our ideas and experiences with others in these forums of the aeronautical profession."

Dr. Sharp observed that the security of the United States depends just as surely on the wisdom and skill of scientists and engineers in the universities and in the laboratories and in the factories as it does on the courage and skill of its fighting men. He said he wondered:

"Who among you will sense and nurture the germ of creation growing in his mind that will spark an advance of the human race?

"Who among you will be awakened by his dreams for the future while others lie contentedly asleep?

"Who among you will rise to the challenges of flight?

"Are there men among you who will help design, construct, or pilot the first practical vertical rising transport that will help shrink the size of our airports?

"Or the first, truly safe, low-cost everyman's aerial flivver that will supplant our automobiles and motor boats?

"Or the nuclear-powered aerial tramp freighter that will endlessly ply the air lanes of the world in useful commerce?

"Or the first manned satellite that will orient man to the problems and wonders beyond our world?

"Or the first argosy that will quest the golden fleece in the far reaches of outer space?

"Or will you men diligently and earnestly advance your chosen profession in more prosaic—but fully as desirable and important—ways?"

Following a review of the challenges of flight of yesteryear, Dr. Sharp listed as the challenges seen ahead:

"Everything indicates that we will soon have exhausted the performance gains possible with fossil fuels and will be seeking to make good the anticipated performance of high-energy fuels and rocket propellants with their many attendant problems.

"Nuclear energy may be applied to a wide variety of propulsion systems and aircraft types with a host of new design, materials, control, and operating problems to solve.

"A functional, integrated system of air traffic control, air navigation, aircraft detection, collision warning, and defense command guidance will undoubtedly be devised and will be generally installed so that pilots will not be in doubt as to their position, or the whereabouts of nearby aircraft, or the location and intensity of en route storms, or the nearness of hazardous terrain, or their chances of making an immediate landing at the airport of their choice.

"An unexpected technological breakthrough may one day make the thermonuclear reaction available for propulsion.

"If and when this happens, and assuming that the extraction and preparation of heavy hydrogen from the sea will require less energy than the thermonuclear reaction produces, we will have it made!

"Our fuel reserves will be virtually limitless!"

Turning to the international race in air prowess, Dr. Sharp declared that "during these crucial days when the world is searching for the means to an enduring and honorable peace, it is vital that we in the United States maintain our qualitative lead in aeronautics with its resulting economy of effective air power.

"Maintaining this lead depends largely on the vigor and skill with which we press our fundamental and applied research.

"With each advance in speed, problems requiring scientific investigation multiply, become more complex, and their solutions more difficult and costly.

"The potential advantages to the cause of world peace if the United States first solves these problems is obvious."

George E. Fouch, MIAS, General Manager of General Electric Company's Evendale Operating Department, is pictured at *right*, below, with members of the 22nd Bomb Wing from March Air Force Base who brought their B-47 Stratojet to the National Aircraft Show in Oklahoma City from Bermuda in the record-breaking time of 3 hours, 8 min., 43.6 sec. to win the General Electric trophy in foreground. Average ground speed over the 1,900-mile course was 601.187 m.p.h. The plane's crew members, *left to right*, were Major Christian Luecke, aircraft observer; Tech. Sgt. James Richardson, crew chief; Capt. Dennis O. Peterson, pilot; and Major Joseph Schrieber, aircraft commander. Six G-E J-47 jet engines power the B-47.

Dr. Sharp warned, however:

"There is no foreseeable position of security which, once attained, will permit us to relax our efforts because science and technology have no limits.

"Forward strides in aviation can only be made through the combined energy of all of us, whether our jobs be in research, production, military or air transportation.

"Our aeronautical scientists and manufacturers must excel, just as the users of aircraft must excel in the services they render."

Turning to the challenges of 1956, Dr. Sharp observed that "progress seems to invent new problems faster than we solve the old ones" and "perhaps not so obvious, even to us in the profession, is the growing complexity of the challenges we face today.

". . .Hypersonic flight, requiring extreme power and generating tremendous frictional heating of the skin, is forcing a new look at research facilities.

"Hypersonic ballistic wind tunnels in which projectiles are fired upstream in a supersonic wind tunnel—multistage rocket-boosted free-flight models, light gas hypersonic shock tubes—these are typical of the radical devices that scientists and engineers need in their continuing search for answers to future design problems.

"The extreme difficulty of reproducing, in the laboratory, sunlike temperatures, meteorlike speeds, and a near-vacuum atmosphere of not clearly understood unstable components is taxing the highest ingenuity of top scientists everywhere.

"And the engineers that will eventually use these environments in their daily work are buying the latest physics books and avidly learning to speak a new language.

"Our future security depends on their ability to make good these new skills while there remains time to put them into practice."

Dr. Sharp spoke before 110 guests and members of the Section at the Atlanta Athletic Club. Chairman A. L. Ducoffe presided. Among guests were representatives of three air lines, Lockheed Aircraft Corporation, and the Civil Aeronautics Administration.

Fred N. Dicerman, FIAS, and Chief Preliminary Design Engineer for the Georgia Division of Lockheed, introduced Dr. Sharp, pointing to his long and varied career in research with the NACA.

American Helicopter Society Holds Third Western Forum

The American Helicopter Society's Third Western Forum was held in Dallas, Tex., on October 7, 8, and 9.

IAS FOUNDER HONORED. Lester D. Gardner, whose tireless efforts 25 years ago nurtured the Institute to a point of healthy adulthood, is pictured above receiving his Elder Statesman certificate from John Victory, NACA Secretary. The presentation was made as many of the Institute Staff and others among his friends looked on at IAS National Headquarters on August 7 at a reception to observe Mr. Gardner's Eightieth Birthday. Sherman M. Fairchild is the interested onlooker.

Speaker at the Forum Dinner on October 8 was Brig. Gen. Carl I. Hutton, U.S.A., Post Commander, Army Aviation School, Fort Rucker, Ala.

There were three technical sessions. They were Design and Development, with Herbert F. Moseley, Project Engineer, Hiller Helicopters, as Chairman; VTOL Aircraft Design and Development; and Test and Operations. Chairman of the former session was Luell M. Graham, Group Engineer, Preliminary Design, Helicopter Division, Bell Aircraft Corporation. Chairman of the latter was Col. Robert R. Williams, U.S.A., President, Army Aviation Board, Continental Army Command.

Design and Development Session papers were "Application of Boundary-Layer Control to Helicopter Rotor Blades," by Sanford Hinton, Design Engineer, Helicopter Division, Cessna Aircraft Company; "Investigation of Operational and Structural Aspects of Tip Mounted Rotor Propulsion," by Raymond M. Lockwood, Research Engineer, Advanced Research Division, Hiller Helicopters; "Helicopter Longitudinal Stability and Control in Forward Flight with Control Feedback," by Kenneth G. Wernicke, Aerodynamicist, Helicopter Division, Bell Aircraft Corporation; and "Development of a Retractable Rotor," by Tadeusz Tarczynski, Project Engineer, Vertol Aircraft Corporation.

Papers delivered at the *VTOL Session* were "Design Considerations for Tilt-Wing Type VTOL Aircraft," by Joseph Mallen and B. McCormick, Vertol Aircraft Corporation; "Tilt-Wing Propelloplane Design Requirements," by Joseph Stuard III, Chief Special Projects Engineer, Hiller Helicopters; "Some Aerodynamic Aspects of Propellers for VTOL Aircraft," by W. F. Grady, Propeller Laboratory, Wright Air Development Center; "The Advantages of the Ducted Propeller in VTOL Aircraft Design," by Norman E. Nelson, Chief Engineer, Doak Aircraft Co., Inc.; and "Development Flight Testing of the XV-1 Convertiplane," by Marvin D. Marks, Chief, Rotor Research, Helicopter Engineering Division, McDonnell Aircraft Corporation.

Test and Operations papers were "High Altitude Operation of Helicopters," by Paul E. Young, Vice-President, Helicopters, Inc.; "Metropolitan Helicopter Taxi Service," by Henry Eagle, Jr., Operations Manager, Cleveland Air Taxi, Inc.; "User Testing of Helicopters by the Army," by Lt. Col. W. H. Byrd, Board No. 6, Continental Army Command; and "Helicopter Operations in South America," by Major Thomas J. Sabiston, U.S.A., Army Aviation School, Fort Rucker, Ala.

On the afternoon of the last day, those attending the Forum toured the Bell Aircraft Corporation's Helicopter Division plant facilities and witnessed an air show at Bell Heliport. Participants, in addition to the Army and Navy, were Bell Aircraft, Brantly Helicopter Corporation, Cessna Aircraft Company, and DeLackner Helicopter Company.

This still photo, snapped as a generalized Air Progress Story took to the West Coast air waves recently, shows Theodore von Kármán, HFIAS, AGARD Chairman for NATO, being interviewed for TV viewers by Red Rowe, of the Columbia Broadcasting System. Many pooled their efforts to put on the "Pan-O-Rama Pacific" telecast, which gave thousands their first closeup views of a variety of engines and aircraft.

Kartveli, Bowman, and O'Donnell Get New Posts at Republic

Promotions and new responsibilities have come to three engineers holding various grades of membership in the Institute as the result of a realignment of key engineering management functions at Republic Aviation Corporation, Farmingdale, N.Y. President Mundy I. Peale, AMIAS, said the realignment will place "increasing emphasis on Republic Aviation Corporation's expanded research and development program."

Alexander Kartveli, FIAS, and member of the Editorial Advisory Committee for the AERONAUTICAL ENGINEERING REVIEW, will devote his full time, as Vice-President in Charge of Research and Development, to heading company-wide research and development activities in aircraft, guided missiles, weapons systems, atomics, nucleonics, and electronics. Mr. Kartveli has been Vice-President and Chief Engineer for Republic, as well as a Director of the corporation.

Richard G. Bowman, AFIAS, and formerly Assistant Chief Engineer for Production, advances to Chief Engineer in Charge of Production and Experimental Engineering. William O'Donnell, MIAS, formerly Assistant Chief Engineer in Charge of Development and Experimental Engineering, has been promoted to Chief Engineer in Charge of Aircraft and Missile Development.

In announcing the changes, Mr. Peale observed:

"Republic has under way many new airplane projects in keeping with the rapid development of aircraft and power plants. In addition, our Guided Missiles Division is enlarging at a very fast rate.

"Mr. Kartveli, in the 25 years he has served in and led Republic's excellent engineering staff, has built a reputation throughout the world as one of the great aeronautical designers of our time. His contributions to the state of the art have been many and outstanding. It is for this reason that he is now planning to use his knowledge and his skill in concentrating on advanced studies, new proposals, and the various research projects that are being undertaken by our own scientific research staff and outside scientists and engineers with whom we regularly consult. He will be in charge of the company's new wind-tunnel program which is now under way. We believe that his assumption of these responsibilities on a direct basis represents a real step forward and will contribute greatly to the quality and performance of aircraft and missiles bearing the Republic name."

Flight-Test Fellowship Worth Almost $5,000

Financial assistance to the tune of nearly $5,000 is assured the successful candidate, or candidates, in the Institute's competition for its 1957 Flight-Test Engineering Fellowship, opened last month.

The Fellowship award has a total value of $4,700. Winning candidates pursue 2 years of graduate study at Princeton University. Second-year renewal is contingent upon satisfactory performance during the first year.

Basic requirements for candidates are a Bachelor's degree in Engineering earned before June, 1957, and United States citizenship.

Application forms may be obtained by a request in writing, endorsed by a sponsoring reference, addressed to Flight Test, Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

The closing date for applications is March 1, 1957.

W. F. Durand Receives Diploma After 76 Years

Seventy-six years between graduation and diploma!

Sounds unlikely, but it has happened to William F. Durand, an Honorary Fellow of the Institute for whom the Los Angeles IAS Building Durand Aeronautical Museum is named.

Dr. Durand, who at 97 is the oldest living graduate of the U.S. Naval Academy, completed his 4-year course there in 1880, when the Academy did not award degrees. A 1933 Act of Congress, however, changed the system, making all graduates eligible for Bachelor of Science degrees.

Dr. Durand did not even have to apply personally for his diploma. Friends in the Navy Department and the Naval Academy Alumni Association arranged for a special presentation in his Brooklyn home on September 5.

White House Names Bassett to Head Airways Study Unit

Preston R. Bassett, an Honorary Fellow and former President of the Institute, now on the Council, is Temporary Chairman of a ten-member team of scientists and engineers which the White House has announced will study long-range needs of the nation's airways.

The group was formed by Edward P. Curtis, who is President Eisenhower's Special Assistant for Aviation Facilities Planning. Its first recommendations are expected at the White House in about 2 months.

George B. Litchford, a Member of the Institute who is serving with another requirements group working under Mr. Curtis, will sit in on meetings of the newly appointed team.

Alexander Kartveli

Richard G. Bowman

William O'Donnell

The White House announcement said the group will "consider the U.S. aviation facilities system in its broadest sense to include the most efficient use of our air space, an adequate airport system, as well as en route, approach, and landing control."

Mr. Bassett is a Sperry Rand Corporation Consultant. Mr. Litchford is Supervisor, Radar and Navigation Section, Airborne Instruments Laboratory.

C. W. Lemmerman, Inc. New Corporate Member

C. W. Lemmerman, Incorporated, a consulting firm specializing in industrial noise problems, has joined the Institute as a Corporate Member.

The organization makes complete sound surveys, works with industrial designers to produce quiet equipment, and specializes in consulting and design of aircraft engine test facilities including noise suppressors for aircraft run-up.

At present, the Company is acting as consultants for several large sound suppressor organizations including industry, the Air Force, and the Navy. Its officials were the pioneers in the development of noise suppression for the aircraft industry. Offices are at 111 Lafayette Street, Hartford, Conn.

Donald Douglas Lauded; Tribute Put in Congressional Record

Donald Douglas, Founder-President of Douglas Aircraft Company, Inc., and an Honorary Fellow and Benefactor of the Institute, has been honored in the *Congressional Record* by Representative Donald L. Jackson, of Santa Monica, Calif.

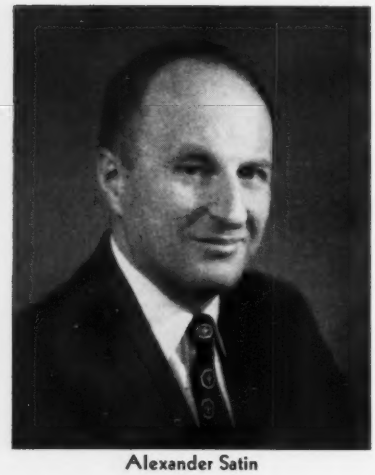
Impressed with the impact on a growing America of Mr. Douglas and his foresight, Congressman Jackson pointed out:

"Donald Douglas has been paid many tributes for his contributions to American aviation, but the greatest living memorial to his genius, his faith, and his steadfastness is the sleek outline of the great plane that bears his name as it streaks through the skies of the world on the many missions upon which it is employed.

"His career is a study in the possibilities of life under the system of legal and free enterprise. With a dream and a dollar Don Douglas did it the hard way, but in going to the top his success assured hundreds of thousands of jobs and unexcelled opportunities for his fellow men."

Following his introduction, Congressman Jackson had inserted in the *Record* a talk by President Douglas outlining the DC series history.

Brussels, Belgium, was the locale for this year's Sixth General Assembly of NATO's Advisory Group for Aeronautical Research and Development, August 27–31. In *top* photo, the Assembly is shown in session in the Auditorium, Ecole Royale Militaire. Panel sessions also were held in this building. In *center*, Theodore von Kármán, AGARD Chairman, stands to open the Assembly. Dr. von Kármán is an Honorary Fellow of the Institute. A fraction of those attending a reception by the Lord Mayer of Brussels in City Hall was caught by the camera in *bottom* photo. Among those pictured are S. Paul Johnston, Director of the Institute, and Robert R. Dexter, Secretary.



Alexander Satin

Satin Wins Service Award for Outstanding Leadership

Alexander Satin, MIAS, Chief Engineer in the Air Branch of the Naval Sciences Division, Office of Naval Research, has been presented with the Meritorious Civilian Service Award by Rear Adm. Rawson Bennett, Chief of Naval Research. Mr. Satin received the award August 14 at a staff meeting.

The award was for Mr. Satin's "outstanding leadership in initiating and coordinating a comprehensive research program in aerodynamics, structures, power plants, instruments, experimental airplanes, helicopters, and other techniques and equipment used in naval air warfare." In addition, the ONR Technical Information Office reported, Mr. Satin has pioneered the development in the United States of VTOL and STOL aircraft.

A fluent speaker of Russian and German, Mr. Satin has contributed to aeronautical knowledge by translating many reports written in those languages. He came to the District of Columbia in October, 1949, following years of teaching in the field of aeronautical engineering and of practical experience with several aircraft companies. These include Boeing, Convair, and Northrop.

Rest Home in Italy May Bear Wilbur Wright Name

An international rest home for pilots on 4,000-ft. Mount Guadagnolo, about 40 miles southeast of Rome, will honor Wilbur Wright if a drive for funds for construction and upkeep is successful.

The land, about 2 acres near the summit, has been donated. Sponsor of the project is Guido Mattioli, publisher of *L'Aviazione*, who met Mr. Wright when the American aviation pioneer helped train Italian pilots in Rome in 1909.

Necrology

Charles J. Lowen, Jr.

Charles J. Lowen, Jr., Administrator of the Civil Aeronautics Administration and an Honorary Member of the Institute, died September 5 in Presbyterian Hospital, Denver. He was 41 years old.

Born in Denver in 1915, Mr. Lowen was educated at the University of Colorado, later becoming active in the commercial aircraft sales field. Qualified in most types of aircraft, he served with the Air Transport Command in World War II and was a Major when he left the service in 1945.

Subsequent positions were Assistant Director of Operations, Capital Airlines, Inc., and Aviation Director, City of Denver. He left the latter post for the automobile business in 1951 but relinquished private business on the request of Mayor Newton, of Denver, to become the city's Manager of Safety. He filled the post for 6 months.

His appointment by President Eisenhower to head the CAA was delayed until last June by a Senate dispute. He is survived by his wife, four children, a brother, a sister, and his mother.

NEWS OF MEMBERS

▶ **Robert H. Korkegi** (M) has taken leave of absence as Research Associate at the University of Southern California for a period of 2 years to assume the position of Assistant Director of the new Training Center for Experimental Aerodynamics, Brussels, Belgium. The Center was established during the Summer by AGARD, of NATO, with support of the belgian government.

▶ **Benjamin Pinkel** (AF), formerly Chief of the Materials and Thermodynamics Research Division, Lewis Flight Propulsion Laboratory, NACA, has joined the staff of The RAND Corporation as Special Adviser on Propulsion Systems.

▶ **G. C. Wainwright, RAF** (AF), has been promoted to Wing Commander and now is associated with the Guided Weapons Department, Royal Aircraft Establishment, Farnborough, Hampshire, England. He formerly was Squadron Leader, RAF, Air Ministry, London.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

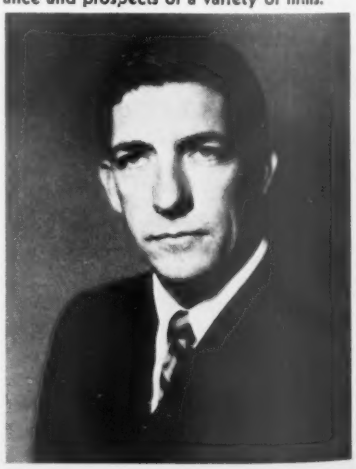
Joseph V. Charyk (M) has joined Aeronutronic Systems, Inc., a subsidiary of Ford Motor Company, Glendale, Calif., as Director of the Aeronautics Laboratory.

Mark Gardner Foster (M), formerly Head of the Development Division, Cornell Aeronautical Laboratory, Inc., has been appointed Director of Research, Crosley Government Products Division, Avco Manufacturing Corporation.

Leonard Goland (M) has joined Kellett Aircraft Corporation as Director of Research. He previously was Chief Project Engineer at Forrestal Research Center and Instructor in the Graduate School, Princeton University.

Gunther R. Graetzer (M) has been named Dean, School of Engineering, Air Force Institute of Technology, Wright-

Najeeb E. Halaby, MIAS, has been appointed Vice-President in Charge of Company Development for Servomechanisms, Inc., Westbury, N.Y. Since 1954, Mr. Halaby has been associated with Mr. Laurence Rockefeller in analyzing performance and prospects of a variety of firms.



A. J. S. Pippard, FIAS, Head of the Department of Civil Engineering, Imperial College of Science and Technology, University of London, has accepted a position as Visiting Professor of Civil Engineering at the Technological Institute of Northwestern University for the academic year 1956–1957. Professor Pippard will present a series of lectures on structural engineering and will act as adviser to graduate students doing research in that field.

Patterson Air Force Base, Ohio. He formerly was Head, Department of Aeronautical Engineering.

Clare W. Harris (M) has been appointed a Project Engineer at the Missile Systems Division, Lockheed Aircraft Corporation. He will continue as Assistant to the Director of Engineering.

Edward P. Hughes (TM) has joined Douglas Aircraft Company, Santa Monica Division, as Weight Analyst, Missiles Weight Section, Missiles Engineering.

Julian H. Kainer (M) has joined Convair, A Division of General Dynamics Corporation, San Diego, Calif., as Design Specialist in Theoretical Aerodynamics.

Frank E. Lenherr (M), former Supervisor of Compressor Design, has been appointed Manager—Component Design and Evaluation, in the Small Aircraft Engine Department of the General Electric Company in Lynn, Mass.

Gerard E. Nistal (AM) has been appointed Account Service Manager by Richard & Gunther, Inc., industrial advertising and publicity agency, of New York. He formerly was Copy Chief.

Lt. Philip F. Oestricher, USMCR (TM) now is attached as a Naval Aviator to Marine Fighter Squadron 114, MCAS, Cherry Point, N.C. Lieutenant Oestricher formerly was a Student Naval Aviator stationed at NAAS, Chase Field, Beeville, Tex.

Glen W. Stinnett (TM) has been promoted from Aeronautical Research Scientist to Aeronautical Research Pilot at Ames Aeronautical Laboratory, NACA, Moffett Field, Calif.

Walter Stubbs (M) has been appointed Assistant to the Executive Vice-President of Air Associates, Inc., Teterboro, N.J. He previously was staff Engineer, Quality Control Manager and Chief Engineer of the Aircraft Products Division.

Karl D. Swartzel (M) has joined Republic Aviation Corporation as Chief Research and Development Engineer of the Guided Missiles Division. He formerly was head of the Physics Department, Cornell Aeronautical Laboratory, Inc.

John R. Westell (TM), former Aerodynamicist with Joy Manufacturing Company, New Philadelphia, Ohio, has become associated as Project Engineer, Blower Development Group, Pesco Products Division, Borg-Warner Corporation, in Bedford, Ohio.

CORPORATE MEMBER NEWS

• **Aeroquip Corporation** announces the acquisition of General Logistics Corporation of Pasadena, Calif. Peter F. Hurst, Aeroquip's President, said the patented products of General Logistics are well-suited to supplement Aeroquip's existing products which include flexible hose lines with detachable, reusable fittings; self-sealing couplings; specialized clamps and couplings; flexjoints; and hot air values. General Logistics, with about 50 employees, produces Weblock strap assemblies, aluminum-alloy tie-down tracks and component fittings, stud attachment fittings, and cargo nets.

• **Air Associates, Inc.,** has announced the appointment to Chief Engineer of Clyde L. Councilman, who has contributed extensively to the development of advanced communications and digital equipment and systems. He will direct the operation and administration of the Engineering Departments responsible for all products developed and made by the company. Prior to his advancement, he served 7 years with the company as Project Engineer and Section Head. . . .The "Talking Beacon," an aircraft radio navigation aid which utilizes a plane's VHF receiver without the need for additional equipment, will be produced by the company on orders from the Army Signal Corps.

• **Aircraft Radio Corporation . . .** A four-page brochure describing its new automatic direction finder system (the Type 21 ADF) is being issued by ARC, Boonton, N.J. The new system weighs less than 20 lbs. and is designed for use on all types of aircraft, especially where weight, size, operating reliability, and minimum air drag are important considerations. As a setting for the new product, ARC has completely revamped one of its three planes. A 7-year-old Ryan Navion now carries the complete ARC line of lightweight communications and navigation equipment.

• **Allis-Chalmers Manufacturing Company . . .** Latest design features of Allis-Chalmers open drip-proof motors in NEMA rerated ratings of 1/2 to 40 hp. (Type G) and in non-rerated ratings of 1/2 to 100 hp. (Types AP and APWW) are described in a new bulletin. Copies are available on request from the company, S. 70th St., Milwaukee.

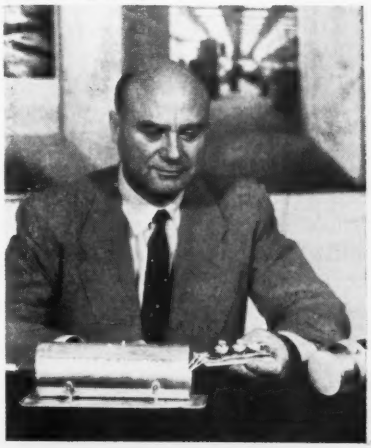
• **Allison Division, General Motors Corporation . . .** Brooks Honeycutt, a former Naval aviator, until recently on the staff of *National Geographic Magazine*, has been appointed Assistant Director of Public Relations.

• **Aluminum Company of America,** cooperating with another firm, reports that a highly wear-resistant coating of sprayed steel on aluminum cylinder walls opens new horizons to designers of the lighter-than-ever all-aluminum engine of tomorrow.

• **Amphenol Electronics Corporation . . .** New 50-contact plugs and receptacles have been added to the line of 115 series connectors produced by the Corporation, 1830 South 54th Ave., Chicago 50. Featuring a vise-action screw lock mechanism for maintaining positive mating under unusual physical stress, the new connectors have a voltage rating of 750 volts rms 60 cps at sea level. Shells are aluminum, hinge hardware is cadmium-plated brass for extra strength, and the handle and screw assembly are made of stainless steel. Male contacts are silver-plated leaded commercial bronze. Dielectric is brown phenolic. Connectors are available with

(*Continued on page 96*)

David Roy Shoults, AFIAS, General Manager of General Electric Company's Aircraft Nuclear Propulsion Department, holds some of the equipment used in a test described by G-E as history's first successful long-range operation of electronic components for atomic reactors at high temperatures and in high-intensity nuclear radiation. Mr. Shoults shows how the component was put in the test capsule before the capsule was placed in an Oak Ridge National Laboratory graphite reactor last June. (Further details on p. 98.)



Editorial

Mid-Term Report

This is the time of the year when we take a preliminary look over our "how-gozit" charts to see what progress we have made during the past 6–8 months. The final accounting must wait for several months until our auditors complete their job. (The annual financial statement is always printed in detail in the March issue of the REVIEW.) Our current records give us a sufficiently good idea of our situation, however, so that we can forecast the eventual score quite accurately. To the great credit of our Controller, Joe Maitan, no final audit has ever differed materially from the running record. Joe has just come back from a swing around the country making a year-end check on our accounting and operating procedures in Los Angeles and San Diego. He has found everything to be in excellent condition. Our Western Manager, E. W. Robischon, seems to have matters well in hand.

Except for a few comments below on our fiscal position, we will leave the dollar details of the annual report for a later issue. The real progress report for the moment can be found in the record of constantly increasing membership and of continually expanding IAS services.

The membership records for the year are most gratifying. Never before in the history of the Institute has the rate of increase matched that of the past 6 months. Here again, no national campaigns have been undertaken. The gains are a direct reflection of increased activity in our Sections. We have always maintained that the real strength of the Institute lies in its Sections and Branches. The IAS will prosper, or it will falter, in direct proportion to the level of interest that is maintained in the Sections.

In this regard, we are most fortunate. Not only is the number of active Sections on the increase (we may reach 30 by the end of the year), but the *quality* of the work done by the Section officers and members is really "first class." Never before have so many done so much for this organization. We of the national organization take this opportunity to thank all officers and committees of all Sections for the splendid record that is being

turned in this year. This is the only way that we can grow and prosper. We pledge to you our interest and support of the work that you all are doing to serve this aviation industry.

The importance of Section support to our Student Branches has been stressed, and results are beginning to show. Our regional student conferences have come to be numbered among the important aeronautical events of the year. Most Sections now have special committees to assist the work of the Student Branches in their areas. Nothing boosts student morale more than to know that senior members of the Institute take a real interest in their work.

In our current program of recruiting personnel for technical and scientific fields in general and for the aeronautical sciences in particular (of which our two vocational guidance booklets are a part), effort expended by Sections in encouraging student participation will pay large dividends.

In our editorial of the past month the expanding activities of the Institute in the international field were pointed up.

An augmented national guided-missile program is well under way. A series of interservice meetings has resulted in planning a comprehensive full-day program on the subject at the January meeting, at which time both military and industry problems will be discussed in open session. A classified seminar under the U.S. Navy, the U.S. Army, and the U.S. Air Force auspices is laid on for mid-November at Holloman Air Force Base and the White Sands Proving Grounds. Early in October a small group of IAS representatives had the privilege of inspecting the installations aboard the Navy's first missile ship, the U.S.S. "Boston." Other programs of this character are planned for the future.

As this is written, Secretary Bob Dexter is again overseas (for the third time this year) attending an AGARD conference in Venice on guided-missile development. On his return trip, he will stop in Germany to discuss collaborative action with the reviving aeronautical societies in Western Germany.

Our publications have never been in better shape. Welman Shrader and his able editorial staff have been implementing our program of increased coverage for the REVIEW, and the traditions of the JOURNAL have been maintained at high level by our new Editor, Dr. William Sears, who relieved Dr. Hugh Dryden early this year. The necessary financial support for all our publications (REVIEW, CATALOG, etc.) derives from advertising—and we are most fortunate in having a real expert in this field on our team. Joe Ryan, well-known and well-liked throughout the industry, is doing a magnificent job in building up revenue to support IAS publishing and other activities. A large portion of the IAS net gain for the current year will be derived from his capable work in the field.

On the overall, the financial picture for the current year is good. Without going into arithmetical detail, our net position will be about the same as it was last year. Our gross income has gone up satisfactorily, but, as is the case in all business operations today, costs have also climbed. Much of our current revenue comes from our publishing operations. Although (as any regular REVIEW reader can easily see) our advertising has increased steadily throughout the year, editorial and printing costs have gone up also, and the difference (our net gain) stays reasonably constant.

Adding all things together, we are now certain that we can report a satisfactory year to the Council and the membership when the books are finally closed. We will recommend to the Council that our reserves against the future be augmented. We are again in the fortunate position of being able to provide the necessary IAS services on an increasing scale and, at the same time, to lay away something to tide us over in any lean years ahead. This we have been able to do without recourse to fund-raising campaigns of any kind. We have no desire to go to anyone with our hat in our hand seeking funds. Our policy for the past decade has been to operate the Institute on a strictly business basis—to be paid only for "services rendered." This we will continue.

S.P.J.

This paper discusses systems for surface protection against transient and continuous heat inputs, corresponding to typical missile and aircraft flight paths. Comparisons of various systems are made for several typical operating conditions.

Surface-Protection and Cooling Systems for High-Speed Flight

D. J. Masson* and Carl Gazley, Jr.*
The RAND Corporation

Introduction

THE HEAT-TRANSFER PROBLEMS associated with high-speed flight can be divided into two categories: (1) high skin temperatures brought about by the increase in boundary-layer air temperature with flight speed and (2) high heat generation by electronic equipment in the aircraft compartments. The compartment heating problems are aggravated by aerodynamic heating and by miniaturization of electronic components.

It is important to note that, while structural materials can be used at higher temperatures than those at which they presently operate, the electronic equipment is limited to rather low temperature levels. The rate at which the allowable temperature level, for electronic components, is being increased is much less than the rate at which thermal operating requirements are increasing. In fact, even now, cooling is an important consideration in the operation of equipment in subsonic aircraft during flight and ground operation.

This paper describes the general heating problems associated with high-speed flight over a broad range of speed, altitude, and time, as well as some of the means available to designers for solving the problems.

Operating Conditions

The range of flight speeds and altitudes considered possible for steady flight are shown in the "corridor" of Fig. 1, which is a modification, by E. P. Williams of The RAND Corporation, of a Figure originally presented by Haber.[1] In the region above the corridor, the dynamic pressure is too low to provide sufficient lift, while below the corridor, the aerodynamic heating rates cause excessive skin temperatures. The present region of steady flight is shown in the cross-hatched portion of the Figure.[2] For the construction of Fig. 1, the maximum allowable skin temperature was considered to be 2,000°F., and the dynamic pressure (necessary for lift) was chosen as 80 lbs. per sq.ft. (except below 1,000 ft. per sec., to allow for helicopters, VTOL, and light aircraft).

The influence of various dynamic pressures and allowable equilibrium temperatures on the extent of the flight corridor is shown in Fig. 2. As the speed of the aircraft increases, the aircraft density probably increases, and the required dynamic pressure increases. Contributing to the weight of the aircraft will be the cooling system required at the high speeds. From Fig. 2 it is seen that considerable higher dynamic pressures do not cut off the flight corridor for allowable skin temperatures of 2,000°F.

Typical flight paths of various types of aircraft, ballistic missiles, glide rockets, and satellite re-entry are shown in Fig. 3, superimposed on a background of the corridor of Fig. 1. Of the flight paths plotted, only the path of the glide missile need be located above the allowable skin temperature curve since it operates at essentially steady-state conditions. The flight paths of the ballistic-type missiles can go below the corridor since the body skin temperatures are governed by the

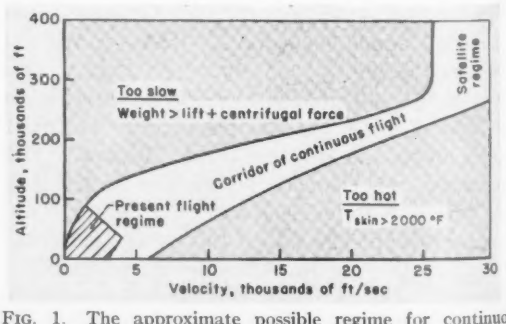


FIG. 1. The approximate possible regime for continuous flight. *Note:* Skin temperature 1 ft. aft of leading edge on flat plate at 5° angle of attack.

Presented at the Aerodynamic Heating: Aerodynamic Aspects Session, National Summer Meeting, IAS, Los Angeles, June 18–21, 1956.

* Engineer.

transient heat input during flight through the atmosphere.

Temperatures and Heating Rates

As a body passes through the atmosphere at various speeds, the temperature it reaches is dependent on the altitude, as well as on the speed. Not only does the atmospheric temperature vary with altitude but the large decrease in density with increasing altitude causes large decreases in the heating rate. Under steady-state conditions, neglecting conduction along the body, the temperature attained by various parts of the body will depend on the radiative characteristics of the surface and the local convective heating rate. The equilibrium temperature will be that at which the emissive power and local heating rates are equal to one another. The constant-temperature curves on Fig. 2 are effectively lines of constant heating rate. Note the large increase in allowable flight speed with increased altitude.

The convective heating rate on the surface of a body flying at high speeds varies along the body surface. The variation in heating rate is most dependent on the local temperature, velocity, density, and distance along the body. Fig. 4 shows, for example, the equilibrium temperature at various points on a cone-cylinder body flying at Mach Number 6. Again, the variation of equilibrium temperature with altitude is illustrated.

Supersonic aircraft and glide missiles operate with essentially steady-state skin temperatures. At a particular flight condition, as the time of flight decreases, the conditions of transient heating begin to influence the operating temperature level of the aircraft. During the flights of long-range ballistic missiles, the convective heating rates and boundary-layer temperature can easily cause the computed skin temperature to exceed the allowable temperature of any known material. In addition to the physical properties of the material, the quantity governing its temperature rise is the total heat input. Typical total heat inputs for various range ballistic missiles are given in Table 1. It is also important to note that the rate at which heat enters a surface may well limit the use of a material as a missile skin. For high heating rates, the outside surface temperature may increase to the melting point value, while the inside surface has not experienced an appreciable rise. To illustrate, take the

Table 1
Representative Total Heat Inputs and Maximum Heating Rates for Long-Range Ballistic Missiles

Range, nautical miles	Total Heat Input, B.t.u./sq.ft.		Maximum Heating Rate, B.t.u./(sq.ft.)(sec.)	
	Laminar	Turbulent	Laminar	Turbulent
500	260	1,500	20	150
1,000	650	4,500	50	420
2,000	1,300	14,000	100	1,400
3,000	2,600	33,500	200	3,600
4,000	2,800	54,000	210	5,300
5,000	3,000	84,000	230	8,200

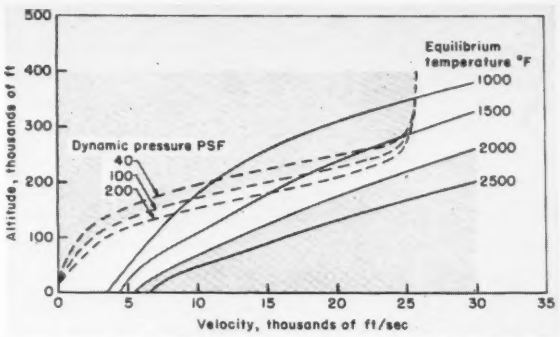


Fig. 2. Variation of velocity vs. altitude for various values of dynamic pressure and equilibrium temperature.

case of 2-in.-thick steel, with a thermal diffusivity of 0.785 sq.ft./hour, subjected to a heating rate of 250 B.t.u./(sq.ft.)(sec.). In 1 min. the heated surface will have reached its melting point, while the other surface has increased only from room temperature to about 1,100°F. For a heating rate of 500 B.t.u./(sq.ft.)(sec.), the surface would reach its melting point after only 15 sec., while the inside surface temperature would rise to 200°F.

During the flight of a ballistic missile, the skin temperature experiences a large variation with time. During the ascent portion of the trajectory, the skin is heated until the convective input and radiation away from the skin are equal. The convective heat input then decreases until, for long-range missiles, it reaches zero. The skin is cooled by radiation while the missile is going over the top of its trajectory. During descent, the convective part of the heat transfer increases; after the convective heating reaches the same value as the radiative cooling, it continues to increase at a higher rate than the radiative cooling. The skin then reaches its maximum temperature sometime during the re-entry part of its flight. An example of the variation of skin temperature with time for a long-range missile is given in Fig. 5.

Surface Protection Systems

A variety of surface-protection systems or techniques have been considered for aircraft and missiles. Generally these techniques consist of providing sufficient mass of structure, so that operation at the flight

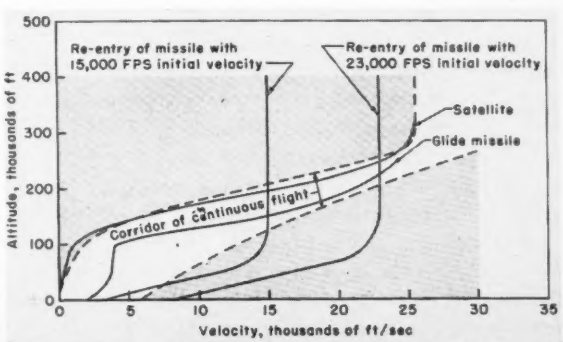

Altitude, thousands of ft
Velocity, thousands of ft/sec
Re-entry of missile with 15,000 FPS initial velocity
Re-entry of missile with 23,000 FPS initial velocity
Satellite
Glide missile
Corridor of continuous flight

Fig. 3. Typical flight paths of high-speed vehicles.

equilibrium temperature can be tolerated, or of absorbing the convective heating, so that the structure can operate below the equilibrium temperature. These latter systems usually consist of heat sinks of various types which absorb heat by virtue of a material's sensible heat capacity, latent heat capacity, or chemical heat capacity—that is, heat absorption is accomplished by a temperature rise, a phase change, or a chemical reaction. Since weight is a prime consideration in either airplane or missile design, a system which absorbs as much heat per unit weight as possible is desirable. The heat-absorbing ability (sensible and latent heat changes) of a variety of common materials is shown in the logarithmic bar graph of Fig. 6. Although there is appreciable variation among the several materials, it is seen that, generally, melting involves the absorption of a few hundred B.t.u./lb., while vaporization absorbs a few thousand B.t.u./lb.

Methods of surface protection to be considered for application to both the steady-state and the transient heating cases are:

(1) Thickening of skin.
(2) Insulation of the outer skin surface.
(3) Cooling of the inner skin surface.
(4) Insulation and internal cooling.
(5) Transpiration cooling.
(6) Mass-transfer cooling.

The applicability and relative efficiencies of each of these systems for various steady-state and transient situations are discussed in the following paragraphs.

Thick-Skin Systems

Perhaps the simplest and most obvious solution to the problem of heat absorption is the use of a thicker metal skin. This serves to increase the available heat capacity, as well as to increase the structure to compensate for the decrease in strength at increased temperature.

For steady flight, in which the skin reaches an elevated equilibrium temperature, an uncooled surface structure must be "beefed up" to counter the decrease in material strength. The increase in weight is a measure of the penalty paid because of the increased operating temperature. In Fig. 7, the effective increase in weight required to withstand the effects of high equilibrium temperature is shown for several aluminum alloys, a titanium alloy, and a high-temperature alloy (Inconel X). Fig. 7a indicates the weight increase for structures in compression, while Fig. 7b shows the situation for structures in tension. For a given equilibrium temperature, the material with the lowest relative weight would presumably be chosen.[3]

For steady flight with the skin operating at the equilibrium temperature, it should be remembered that additional weight penalties may be incurred through the necessity of protecting the interior of the vehicle from the high temperature of the outer structure. This could be accomplished through the use of an insulation on the inside surface of the skin, by a compartment cooling system, or by some combination of these systems.

For the case of transient heating accompanying some aircraft flight programs and many missile applications, thick metal skin also serves as a heat sink. Here, however, it may be necessary to consider the transient heat conduction within the skin itself. In the case of rapid transients, appreciable temperature gradients may develop across even rather thin skins. For skins of moderate thickness, the temperature rise at the outer surface is relatively insensitive to thickness—i.e., the material at the back of the skin is ineffective as a heat sink since it does not "feel" the heating at the outer surface. For extremely high speeds, with equilibrium temperatures above the melting point of the skin material, the outer surface may melt while the inner surface experiences only a moderate increase in temperature. The absorption of transient heating by temperature rise and melting of a thick skin occurs in nature when a meteor enters the earth's atmosphere. A meteorite which succeeds in reaching the earth's surface sacrifices an appreciable portion of its mass while passing through the atmosphere.

The characteristics of the transient heat conduction into skins are available for a variety of heat input functions.[5, 6] These solutions indicate that thin skins of relatively high thermal diffusivity can be treated simply as capacitances with uniform temperature rise, while thicker skins of lower thermal diffusivity result in appreciable temperature gradients. An approximate criterion for judging the severity of temperature gradients across a skin under transient heating conditions can be formulated from a dimensionless skin thickness

$$l^+ = l\sqrt{q_{max}/\alpha Q}$$

where l is actual thickness, q_{max} is maximum heating rate, Q is the total heat load, and α is the thermal diffusivity. For values of l^+ smaller than about 0.1, the temperature rise is essentially constant across the skin—i.e., the skin may be treated as a capacitance. For l^+ greater than about 2, the surface temperature rise is independent of thickness and the back of the skin undergoes a negligible temperature rise.

The performance of a steel skin is shown in Fig. 8 under conditions where the heating rate increases exponentially with time, such as occurs for the entry of a ballistic missile into the atmosphere. In this Figure, the action of various skin weights is indicated as a function of total heat load—i.e., the varying heating rate integrated over the time of heating. Regions are mapped for the conditions at the end of the heating period, for a skin with an initial temperature of 100°F. In the region at the upper left, corresponding to thick skins and low heat loads, a mean temperature rise of less than 1,400°F. occurs and the surface temperature does not reach the melting point. To the right of this region, surface melting occurs, but some strength retention is maintained since the mean-temperature rise is less than 1,400°F. For thinner skins than encom-

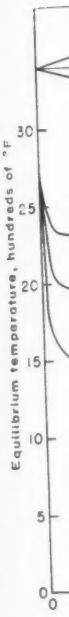
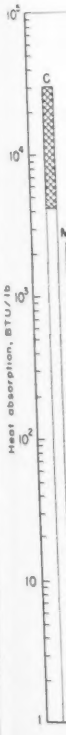


FIG. 4. V



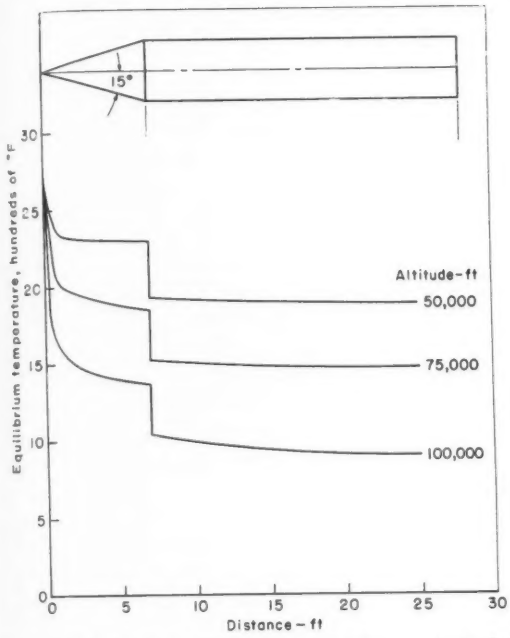


FIG. 4. Variation in equilibrium temperature on a body flying at $M = 6$ for various altitudes.

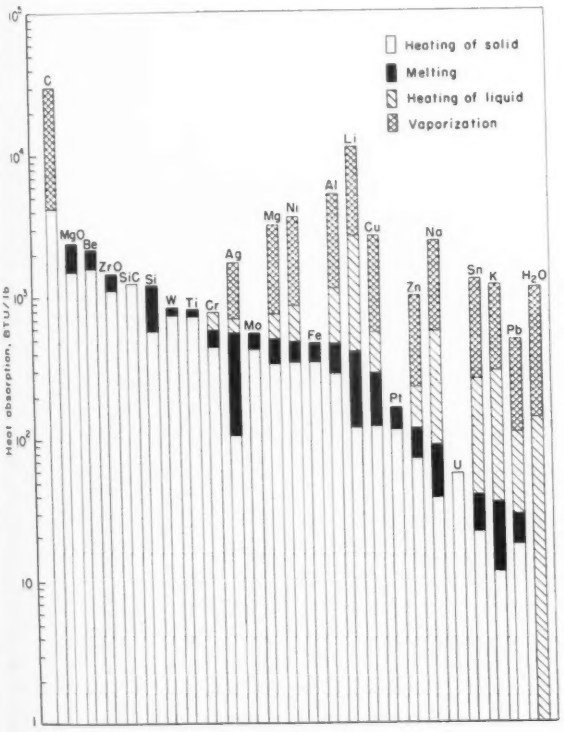


FIG. 6. Heat absorption of various metals.

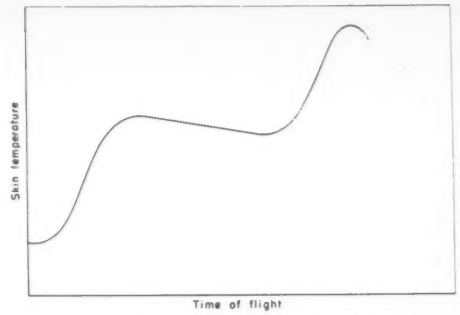


FIG. 5. Variation of skin temperature with time for typical ballistic missile flight.

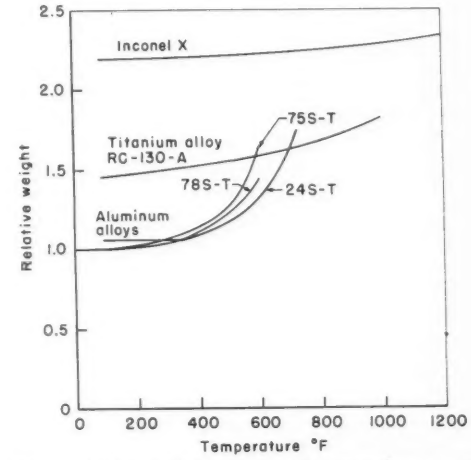


FIG. 7a. Relative weight for metals operating at various temperatures in compression.

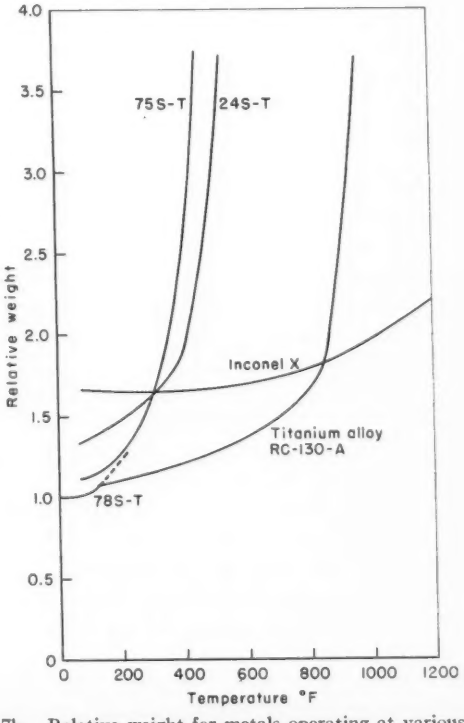


FIG. 7b. Relative weight for metals operating at various temperatures in tension.

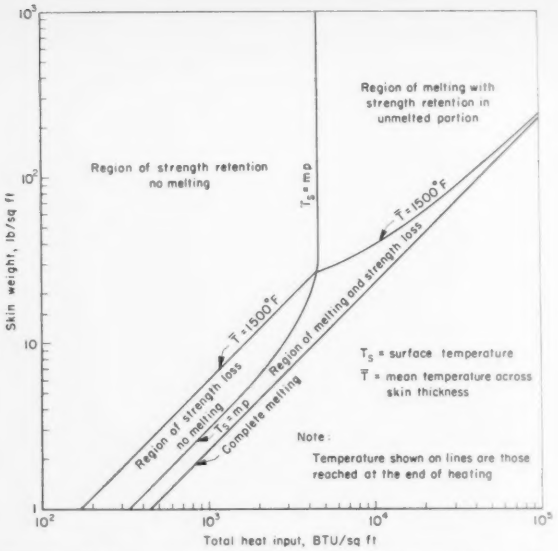

Region of melting with strength retention in unmelted portion
Region of strength retention no melting
T_s = m.p.
$\bar{T}$ = 1500°F
$\bar{T}$ = 1500°F
Region of melting and strength loss
Region of strength loss no melting
T_s = m.p.
Complete melting
T_s = surface temperature
$\bar{T}$ = mean temperature across skin thickness
Note:
Temperature shown on lines are those reached at the end of heating
Skin weight, lb/sq ft
Total heat input, BTU/sq ft

FIG. 8. Performance of steel skin for a heating rate increasing rapidly with time.

passed in the two upper regions of Fig. 8, a mean-temperature rise of more than 1,400°F. occurs. In the region at the lower right, the skin has been, at the end of the heating period, completely melted away without absorbing all of the heat. It is interesting to note that surface melting always occurs when the heat load is greater than a certain value; this essentially corresponds to a heat rate so high that it cannot penetrate appreciably into the skin—i.e., l^+ of about 2.

The requirements of skin weight necessary to absorb a given heat load, while still maintaining some structural strength, are given in Fig. 8 by the line labeled $\bar{T}$ = 1,500°F. (1,500°F. being arbitrarily chosen as a strength criterion) which corresponds to a maximum mean temperature of 1,500°F. for the unmelted portion of the skin. Similar charts could be prepared for other materials and other heat input functions. In a detailed design study, it is expected that a variety of skin materials would be investigated, the final choice depending on both structural and thermal properties. The oxidation characteristics of the material should also be considered; some materials may require an oxidation-resistant coating and should be used only for cases where melting does not occur.

Insulation on the Outer Skin Surface

The use of an insulating coating on the outside of the structural skin has certain advantages in both the steady-state and transient cases. Insulating coatings allow some separation of the structural and thermal design requirements—that is, the structural skin material can be chosen for its desirable structural properties and the coating material for its insulating, oxidizing, and heat-absorbing properties. Furthermore, by the use of a high-temperature coating, the outer surface temperature may be allowed to reach values high enough to reduce appreciably the convective heat input and to increase appreciably the heat dissipation by radiation.

For steady high-speed flight, the primary advantage of an outer insulating coating lies in the reduction in the operating temperature of the inner structural skin. To accomplish this, of course, some form of cooling at the inner skin is necessary. However, the cooling requirements are appreciably reduced because of the reduction in heat flux by the insulation. As the insulation thickness is increased, for a given flight speed, the internal cooling requirements are reduced. It is possible to compute an optimum insulation thickness corresponding to a minimum combined weight of insulation, structural skin, and internal cooling system. Fig. 9 shows such results for three flight equilibrium temperatures, a lightweight insulation, and an internal cooling system using boiling water as an expendable coolant for steady flight of 1 hour's duration. In this Figure the total combined weight (insulation, skin, and cooling system), relative to a 0.2-in. aluminum skin, is shown as a function of insulation thickness for each flight equilibrium temperature. It is seen that optimum conditions correspond to insulation thickness which increases gradually with flight equilibrium temperature. These optimum insulation system weights (again relative to a 0.2-in. aluminum skin) are shown in Fig. 10 as a function of flight equilibrium temperature. Also shown is the required relative weight for a thick uncooled skin (from Fig. 7a). The use of an insulation system is seen to be advantageous for flight equilibrium temperatures greater than about 900°F. At a flight equilibrium temperature of 1,500°F., the insulation system is about 35 per cent lighter than the uncooled thick metallic skin.

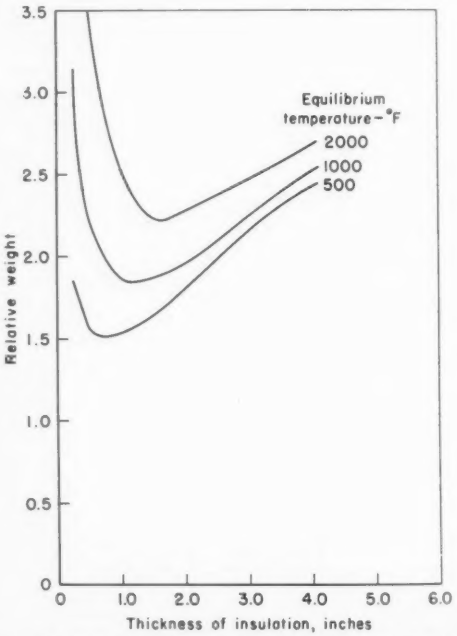


FIG. 9. Variation in relative weight with insulation thickness for various surface equilibrium temperatures for a lightweight insulation on outside surface. (Flight time—1 hour.)

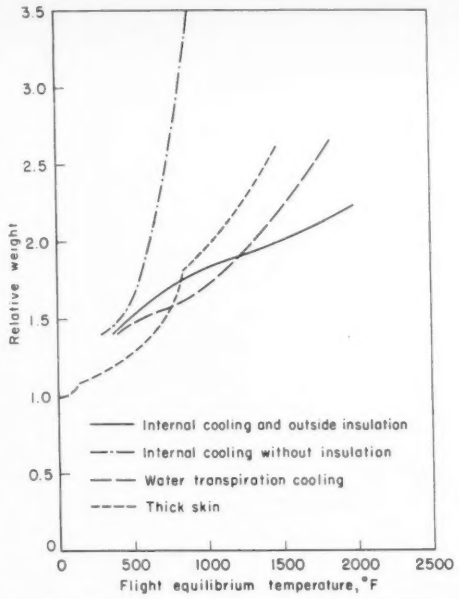


FIG. 10. Weight comparison of various steady-state cooling systems.

The use of insulation in steady flight is conditioned by its temperature limitations. Since the outer surface of the insulation will attain a temperature only slightly below the flight equilibrium temperature, it cannot be used for flight conditions in which the equilibrium temperature exceeds the allowable operating temperature of the insulation. The curve for the insulation system in Fig. 10 would, therefore, terminate at a certain flight equilibrium temperature.

In the transient situation, the use of an insulating coating serves to absorb some of the incoming heat and to reduce, as well as delay, the temperature rise of the structural skin. Of course, the advantages of separating structural and thermal design requirements and the increase in heat dissipation by radiation are also present. Analysis of transient heat conduction in multilayer slabs[5] indicates that the desirable properties of a transient insulation, or "transulation," are somewhat different from those for a steady-state insulation. A good transulation should have a low thermal diffusivity $\alpha = k/\rho c$ combined with a relatively high thermal conductivity. This effectively means a large thermal capacitance, ρc. The action of a good transient insulation can be pictured physically as the insertion of a good heat sink between the heat source and the material to be protected.

To indicate the effect of a transient insulation, the performance of a steel skin with a ceramic coating is pictured in Fig. 11 for the same type of transient heating imposed on the steel skin alone in Fig. 8. Regions are mapped for various conditions in the insulating coating and in the underskin at the end of the heating period. It is interesting to note that the limiting heat load, above which melting always occurs, is appreciably less than for the steel alone. This is due to the lower thermal diffusivity of the ceramic.

TABLE 2

Convective Heat Input, B.t.u./sq.ft.	Surface Temperature, °R.	Radiation Cooling, B.t.u./sq.ft.	Net Heat Input, B.t.u./sq.ft.
10,000	2,000	150	9,850
10,000	5,000	6,000	4,000

If we again choose 1,500°F. as the maximum allowable skin temperature of the steel underskin, the weight of the ceramic-steel combination is given by the curve in Fig. 11 labeled $T_2 = 1{,}500°F$. Comparison of this with the similar curve in Fig. 8 indicates the appreciable weight-saving accomplished through the use of the insulating coating. It should be pointed out that the advantage of a high-temperature insulating coating in dissipating heat by radiation does not appear in a comparison of Figs. 8 and 11. For example, if a heating situation corresponded to a convective heat load of 10,000 B.t.u./sq.ft., a surface having a temperature of 2,000°R. would result in net heat input of 9,850 B.t.u./sq.ft., while a surface temperature of 5,000°R. would result in a net heat input of only 4,000 B.t.u./sq.ft. (see Table 2).

Internal Cooling

The purpose of an underskin cooling system is to absorb heat from the outer skin to prevent its overheating, as well as to prevent the transfer of heat to the interior of the vehicle. Such a system consists of a material behind the outer structural skin which absorbs heat passing through the skin. For example, water boiling behind the skin would be a possible internal cooling system. The skin temperature level is, of course, determined by the aerodynamic heating rate at the outer surface, as well as by the rate at which heat is absorbed at the inner surface of the skin by the coolant.

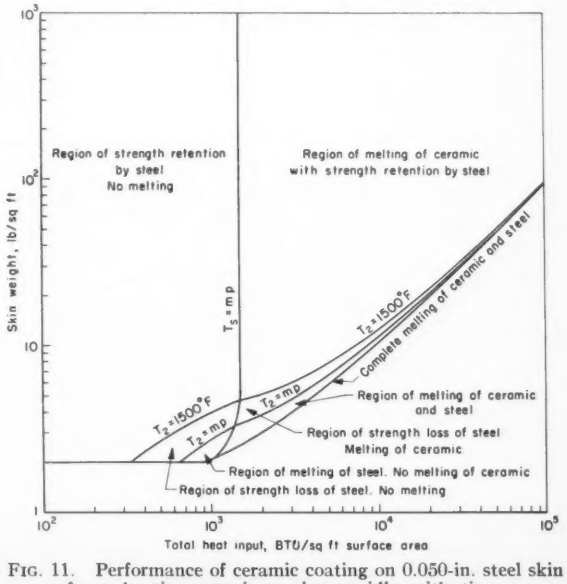

Skin weight, lb/sq ft
Total heat input, BTU/sq ft surface area
Region of strength retention by steel No melting
Region of melting of ceramic with strength retention by steel
T_2=1500°F
Complete melting of ceramic and steel
T_2=m.p
Region of melting of ceramic and steel
Region of strength loss of steel Melting of ceramic
Region of melting of steel. No melting of ceramic
Region of strength loss of steel. No melting

FIG. 11. Performance of ceramic coating on 0.050-in. steel skin for a heating rate increasing rapidly with time.

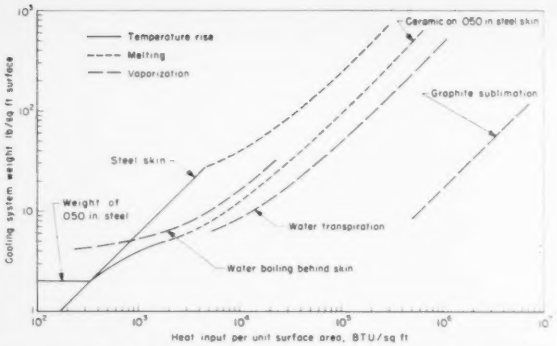


FIG. 12. Comparison of various cooling systems for transient heating.

In either a steady-state or a transient high-temperature situation, the limitation of such a system is the ability of the material behind the skin to absorb heat at a sufficiently high rate to prevent the outer skin from overheating. Even with an infinite heat-transfer rate between the skin and the coolant, the temperature of the outer skin surface may become excessive—that is, the thermal resistance of even a thin metal wall cannot be overcome by infinite cooling at the inner side. For example, if one were to maintain the inner side of a 0.050-in. steel skin at 300°F., a heating rate at the outer surface of about 7,000,000 B.t.u./(hour)(sq.ft.) would produce melting at the outer surface and a mean skin temperature of 1,500°F. In such a case, the heat-flow rate and the metal temperature could be reduced by the use of an external insulation as described in the previous section.

The weight of an internal cooling system for steady-state heating may be divided into a fixed weight (cooling liner, plumbing, pumps, and control systems) and a variable weight (either expendable coolant or an equivalent amount of fuel which must be expended to refrigerate the coolant). The total weight can be estimated as the sum over a fixed time period. Since flight at speeds requiring a cooling system will probably not be of long duration, we may arbitrarily choose some relatively short period of time—say 1 hour, for purposes of comparison. The weight requirements are shown in Fig. 10 as a function of flight speed for a system using water boiling behind the skin (and being ejected as vapor or condensed in a refrigeration device and recirculated), both with and without external insulation. Without insulation, such a system is seen to be less efficient than a thickened skin.

A somewhat different situation exists in the transient heating situation. A system involving water boiling under an uninsulated skin is shown in Fig. 12 as weight required for various heat loads in comparison with the transient protection systems previously discussed. While it is more efficient than the thick metal skin, it is less efficient than the transient insulation system. Furthermore, it is limited to a certain heat load if melting of the outer surface is to be avoided. For larger allowable heat loads, an insulation could be added to the outside of the skin. This would lower the metal temperature, reduce the heat flow to the cooling water, and increase the efficiency slightly.

Transpiration and Mass-Transfer Cooling Systems

Systems using transpiration and systems using mass transfer from the outer surface of the vehicle will be considered together since they involve essentially the same physical processes and differ only in technique. A transpiration system consists of the controlled pumping of a gas or vapor through a porous skin; a mass-transfer system involves the sublimation (self-controlled) of the outer surface of the skin itself. Although these systems are still in relatively early stages of development, they offer probably the highest efficiencies of any system considered and the greatest ultimate promise for extremely high flight speeds. This is due to the effect of the gaseous discharge from the surface in reducing the incoming convective heating. The efflux of gas outward from the surface warps the velocity and temperature profiles in the boundary layer and materially reduces both the heat-transfer coefficient and the temperature-recovery factor. Although the degree of reduction of the convective heating at supersonic and hypersonic speeds is still a matter of conjecture, theoretical and experimental work at low speeds[7] indicate that it may be appreciable. This type of system also has the advantage of providing cooling at the outer, rather than the inner, skin surface.

An example of a transpiration system is water-transpiration cooling in which liquid water is pumped into the back of a porous skin and vaporized within the skin, water vapor emerging from the outer porous surface. This system is more efficient than water boiling under the skin and can be extended to higher heat flow rates since the entire thickness of the porous skin is cooled by the fluid passing through it. The increased efficiency due to the vapor efflux is partially counteracted by the weight of auxiliary equipment such as storage tanks, pumps, and other plumbing.

Less complicated than transpiration is the use of a surface coating which sublimes or chemically dissociates. Suggested materials include gypsum, magnesium nitride, and graphite. Such coatings eliminate the complication of a porous skin, the weight penalty of plumbing, and the necessity of control.

The relative weight requirements for a water transpiration system in steady flight are shown in Fig. 10 in comparison with the other systems discussed previously. At low flight equilibrium temperatures, all of the cooling systems suffer from the fixed weight of liners, plumbing, pumps, etc. As the flight equilibrium temperature increases, however, the cooling systems become more efficient than the thickened uncooled skin. The water transpiration system is slightly more efficient than the insulation system for flight equilibrium temperatures between about 800 and 1,200°F. For higher flight equilibrium temperatures, the insulation system becomes more efficient and would presumably be used up to the point where temperature limitations of the insulation would prevent

its use. At still higher flight equilibrium temperatures, transpiration or mass-transfer systems would take over since they are not restricted by temperature or heat-flux limitations.

Transpiration and mass-transfer systems offer similar advantages for transient situations. A water transpiration system and a graphite sublimation system are shown in Fig. 12 in comparison with the transient systems previously discussed. The water transpiration system is shown only for the higher heat loads where it is more efficient than the transient insulation system. It is, of course, appreciably more efficient than the internal cooling system using water boiling behind the skin. Because of the extremely high heat absorption accompanying the sublimation of graphite (about 25,000 B.t.u./lb.), the graphite sublimation system is the most efficient for high heat loads. Current consideration of such a system suffers, however, from a lack of knowledge of the interactions between the surface and the boundary layer. For example, the question of whether graphite would burn, rather than sublime, is a complicated one—involving simultaneous consideration of heat transfer, mass transfer, compressible fluid mechanics, and chemical reaction kinetics—and can probably be settled only by test.

Compartment Cooling

For compartment cooling at high flight speeds, the types of systems available for the dissipation of heat generated by the compartment equipment are limited. The limitation occurs mainly because atmospheric air can no longer be used as an ultimate heat sink.

The regime of flight where most detailed analyses of cooling systems have been carried out is in the Mach Number and altitude ranges shown by the cross-hatched portion of Fig. 1. Here the cooling systems, for the most part, depend on either ram air or bleed air from the engines. In the high-speed, high-altitude region, the quantities of air required for cooling compartments become very large because the air density at high altitudes is reduced. Also, because of high speeds, a lower temperature potential is available to transfer the heat, thus requiring a hihger weight rate of flow and further increasing the quantities required. The operating temperatures of equipment must be kept low, and this in turn limits the temperature of the cooling air that can be used. Examples of the variation of cooling system requirements with flight speed are shown in Fig. 13[8] for some low-speed cases. Fig. 14 shows the general regions where reasonable operation of various types of cooling system are most applicable.[9]

It was pointed out above that, as the flight speed increases, some of these systems for ultimate heat dissipation become impractical. Expendable coolant, radiative cooling, and fuel cooling systems, however, can still be considered since they do not depend on the atmospheric air for their operation. The transient behavior of the compartment equipment, along with the structure, can also be considered as a means of dissipating heat in high-speed cases since the flight times at high speeds will usually be short.[10] (It is evident that for speeds of over 3,000 ft. per sec., 6 hours would give an exceedingly long range—one-half way around the earth. Except for satellites, flight times are probably, at most, 2 hours.)

Cooling systems must be designed to maintain the structure at the proper temperature level and dissipate the heat generated by the equipment and the heat entering the compartment from the outside. Since equipment usually has lower temperature limits than the structure, it should be packaged in compartments rather than scattered throughout the interior of the aircraft so that the whole internal volume of the aircraft does not have to be maintained at a temperature level suitable for equipment operations.

Fuel Coolant

The use of fuel as a coolant for structures and equipments is not particularly advantageous. Rocket,

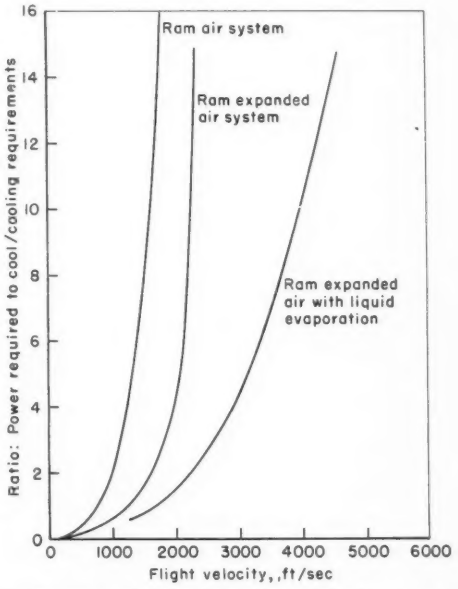


Fig. 13. Power required for cooling for various low-speed cooling systems.

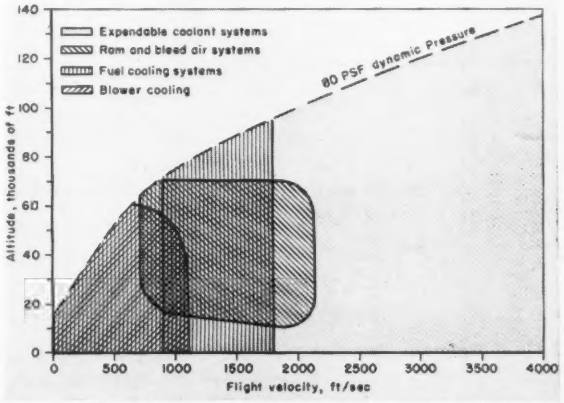


Fig. 14. Operating regions for cooling systems applicable to low-speed flight.

ram-jet, and turbojet engines are presently designed to use liquid fuels, and therefore only the sensible heat of the liquid is available for absorbing heat. In some cases the fuel could be vaporized, taking advantage of its latent heat of vaporization. However, the fuel then acts as an expendable coolant, and, except for a small operating region, other fluids are better. The problems connected with increased temperatures of liquid fuels usually overtake the advantage of being able to "dump" heat into the readily available heat sink. The main problem associated with increased vapor pressure is that heavier construction of tanks, lines, etc., is required in order to prevent cavitation problems in pumping and fuel loss due to evaporation.

Expendable Coolants

From Fig. 14 it is seen that expendable fluids begin to be competitive as coolants for speeds even as low as 900 ft. per sec. for the entire altitude and speed range under consideration.

In comparing fluids for use as expendable coolants, the thermal properties, specific heat, and latent heat which govern the amounts of heat that they can absorb are to be considered. If the fluids are required to flow through lines, the viscosity and density are important from the standpoint of pumping power required. For short flow distances, the heat-transfer properties are most important. The heat-absorption capacity of several fluids is given in Table 3.

It is evident from Table 3 that water appears to be the best heat-transfer fluid since its latent heat of vaporization and ability to absorb sensible heat are the highest of the fluids listed. It is possible that the advantage of water over the other fluids may be lost in some cases when the whole cooling system operation is evaluated. This might occur in the case of short-time flight since less apparatus might be required if a fluid already on board, such as fuel, is used and the equipment is near the fuel system. For long-flight times and for unpowered flight, such as those associated with ballistic and glide missiles, the systems utilizing water would be superior. This general trend is illustrated in Fig. 15.

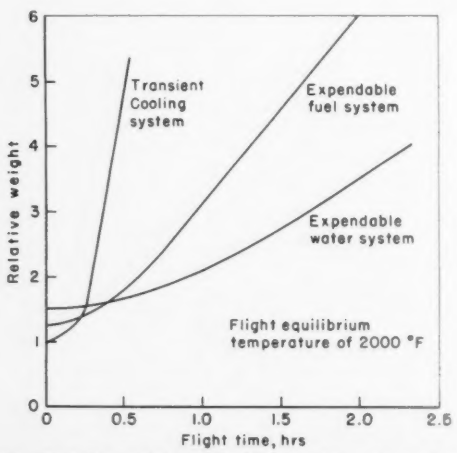


FIG. 15. Relative weight variation vs. flight time of cooling systems.

TABLE 3
Properties of Fluids at One Atmosphere Pressure*

Fluid	Latent Heat of Vaporization, B.t.u./lb.	Specific Heat, B.t.u./(lb.)(°F.), Liquid	Boiling Point
Water	970	1.0	212
Methyl alcohol	482	0.6	148
Ethyl alcohol	367	0.55	173
Petroleum fuels	150	0.5	170
Acetone	240	0.54	133

*From *Mechanical Engineer's Handbook*, Marks, L. S. (Ed.), 5th Ed.; McGraw-Hill Book Company, Inc., New York, 1951, and *Chemical Engineer's Handbook*, Perry, J. H. (Ed.), 3rd Ed.; McGraw-Hill Book Company, Inc., New York, 1950.

Radiative Cooling

The use of radiative cooling is limited to extremely high altitude flight where the equilibrium temperatures of the aircraft surface are low. Since the rate at which heat can be radiated per unit surface area is quite low, the surface areas required are necessarily large.

Radiative cooling will be most applicable in the case of satellite vehicles. Here the internal heat generations will be very small, and only a few degrees rise in skin temperature over its equilibrium temperature will be required. As an example, the IGY satellite with a diameter of 20 in. would experience, at most, a skin temperature only about 10°F. above its equilibrium temperature.

Transient Cooling

Since short flight times are expected during high-speed flight, in many cases it will be found that no provision is required for cooling the equipment. Even if a cooling system is required, the weight penalty of the cooling system can be considerably lessened by taking advantage of the transient behavior of equipment.

For short-flight times, it may well be that most of the equipment which is temperature limited will not overheat, but certain critical items will. Naturally large savings in cooling penalty can be realized by specially designing or cooling only these critical items.[10]

Transient cooling analysis is important for a bomber or fighter during a supersonic dash, for re-entry of ballistic missiles, and for extremely high-speed flight such as that connected with glide rockets.

TOTAL COOLING REQUIREMENTS

Various means for ensuring satisfactory thermal operation of aircraft structures and equipment have been discussed. It is of interest to consider the weights of these individual systems in order to get an idea of the total weight penalty that might be expected for some typical flight condition.

It has been pointed out that the allowable temperature level of the equipment and structure have a marked influence on the weight of the cooling system to be used. In general the weight of cooling systems required for compartment cooling will be considerably less than those required for maintaining the structure at the proper level. This is for reasonable amounts of heat-dissipating equipment in the compartments.

For example, in the case of steady flight of an aircraft with an outside surface area of 300 sq.ft., the total increase in weight necessary for protection of the structure might be about 1,000 lbs. when flying at conditions of 2,000°F. equilibrium temperature for 1 hour. The weight of a compartment cooling system for 15 kw. dissipation would be about 100 lbs. As the equilibrium temperature decreases, the weight penalty for maintaining suitable structural temperatures decreases appreciably, while the compartment cooling system weight does not decrease as much in proportion.

Conclusions

Although the high flight speeds contemplated for aircraft and missiles involve high aerodynamic heating rates, systems for cooling internal compartments and for cooling or protecting the surface appear feasible for both steady and transient heating situations. The weight requirements for these systems increase with flight equilibrium temperature and with the time of flight. For the lower range of flight equilibrium temperatures or lower transient heat loads, a thickened metallic skin appears to be the most efficient means of countering the surface aerodynamic heating. In this range, cooling of internal equipment by ultimate dissipation to atmospheric air seems most feasible. For higher flight equilibrium temperatures and higher heat loads, surface protection is best accomplished by insulation of the outer structure and by internal cooling—or by a transpiration or mass-transfer system. Cooling of internal equipment in this range is most efficiently accomplished by an expendable vaporizing coolant or by the thermal capacity of the equipment and structures themselves.

References

[1] Haber, F., *The Heat Barrier*, Scientific American, December, 1953.

[2] Carhart, N. A., *The Problem of Cooling Electronic Equipment in High Performance Aircraft*, IAS Preprint No. 612, January, 1956.

[3] Gerard, G., *Some Structural Aspects of Thermal Flight*, Symposium on the Thermal Barrier, ASME, 1954.

[4] Schnitt, A., *et al*, *Optimum Stresses of Structural Elements at Elevated Temperatures*, Symposium on Structures for Thermal Flight, ASME Paper No. 56-AV-11, 1956.

[5] Coulbert, C. D., *et al*, *Temperature Response of Infinite Flat Plates and Slabs to Heat Inputs of Short Duration at One Surface*, University of California, Report for AF Contract 33(038)-1-1381, April, 1954.

[6] Gazley, C., Jr., Huth, J. H., and Horn, M. C., *Transient Heat Conduction in Composite Slabs for a Heat Flux Varying Exponentially with Time*, The RAND Corporation, Research Memorandum RM-1524, July 22, 1955.

[7] Eckert, E. R. G., *Transpiration and Film Cooling*, Heat-Transfer Symposium, University of Michigan, Ann Arbor, Mich., 1953.

[8] Adams, H. W., *Temperature Problems of Equipment in High Speed Aircraft*, Symposium on the Thermal Barrier, ASME, 1954.

[9] Robinson, W., and Zimmerman, R. H., *Methods for the Ultimate Dissipation of Heat Originating with Airborne Electronic Equipment*, AF-WADC TR 6493, March, 1951.

[10] Paselk, R. A., *Transient Thermal Behavior of Equipment and Its Relation to Aircraft Cooling Systems*, Paper presented at ASME Heat Transfer Division Meeting, Los Angeles, Calif., November 15, 1955.

[11] Kallmann, H. K., *Physical Properties of the Upper Atmosphere*, The RAND Corporation, Research Memorandum RM-841, May 12, 1955.

[12] Geankoplis, C. J., *et al*, *Heat Transfer Fluids for Aircraft Cooling Systems*, AF-WADC TR 54-66, February, 1954.

[13] Zimmerman, R. H., and Robinson, W., *Equipment Cooling Systems for Aircraft*, AF-WADC TR 54-359, September, 1954.

Now Available

Proceedings of the Third National Turbine-Powered Air Transportation Meeting

San Diego, Calif.—August 15–17, 1956

Contains papers and technical discussions presented at this meeting, complete with figures and illustrations.

Member Price, $3.50 **Nonmember Price, $6.00**

Copies may be obtained by writing to: **Publications Department, Institute of the Aeronautical Sciences, Inc. 2 East 64th Street, New York 21, N.Y.**

Lewis H. Abraham*
Douglas Aircraft Company, Inc.

Techniques and Problems in Testing Structures at Elevated Temperatures

The simulation of aerodynamic heating by various methods in order to follow the load-temperature-time experience of a high-speed vehicle.

Introduction

Seldom, if ever, in man's history has one branch of the sciences been able to remain static while the others advanced. A new problem has always required new techniques in its solution. Structural testing is no exception.

With the advent of vehicles traveling at supersonic and hypersonic speeds and their attendant aerodynamic heating and split-second loadings, new techniques of structural testing have become necessary. The days of piling on lead and leisurely recording data can now be looked back upon as "the good old days." In the time it once took merely to apply a test load, some missiles could have completed their entire service life. During this short interval of time, a missile could have experienced many varied load patterns and could have been heated, cooled, and heated again in the miles of flight path it would have covered. Where flight missions were once measured in hours, one now speaks in terms of seconds.

These events have fallen with a heavy impact on the test engineer. The added complexity of thermal stresses, thermal gradient, creep, and attrition due to melting or erosion has reduced the confidence in the analytical treatment of many structural problems and has thus increased the quantity and quality of structural testing necessary to substantiate a design. Axiomatically, if faith in structural testing is to be well founded, the load-temperature-time history of the structure will have to be closely followed or the results will be misleading.

The Problem of Simulation of Aerodynamic Heating

Aerodynamic heating is the principal source of heating of a high-speed vehicle. Though power plants may provide local trouble spots, the outer skin, exposed to the hot boundary layer, is by far the most critical facet of the problem. It is this phenomenon which the test engineer will find most difficult to simulate.

Fig. 1 gives the variation of stagnation temperature with Mach Number and altitude. This curve illustrates the magnitude of the temperature environment in which a missile or airplane will have to operate.

The heat flux generated by this environment, in the turbulent flow region of a 20° cone, is shown in Fig. 2. It will be noted that most aerodynamic heating takes place below 75,000 ft. These are the quantities of heat flow that the test engineer will be required to simulate.

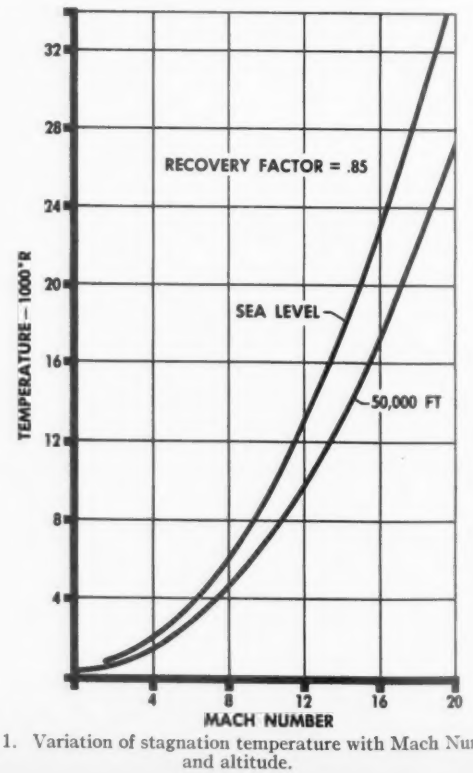


Fig. 1. Variation of stagnation temperature with Mach Number and altitude.

Presented at the Aerodynamic Heating: Structural Aspects Session, National Summer Meeting, IAS, Los Angeles, June 18–21, 1956.

* Chief, Missiles Strength Session, Santa Monica Division.

Obviously, the power required, except for the lower Mach Numbers, precludes the simulation of the aerodynamic heating on the entire body simultaneously.

A missile traveling at a speed corresponding to a Mach Number of 25 at sea level would be subjected to a heat flux of the order 12,500,000 B.t.u./ft.²/hour. This represents an input of almost 5,000 hp. per sq.ft. Stated another way, it would be the flux from a body with an emissivity of 0.8 and a surface temperature of 10,000°F., the temperature usually attributed to the sun's surface. The futility of trying to simulate fluxes of this magnitude is obvious. The only way this can be accomplished is in actual free flight.

The highest flux available today is that obtainable at the focal spot of a solar furnace, an extremely small area. Even so, this device is only theoretically capable of producing about this quantity of heat. Practically, less than half this heat flux is obtainable in the best available installations.

Other methods of heating have even lesser capabilities, and in laboratory testing, where practical sizes of structural units are involved, we must confine our efforts mostly to these lower heat-producing devices. These should not be disparaged however, for considerable flight range can be simulated with them. Further development should even extend their usefulness.

Heating Methods

In attaining the heat flux necessary to simultate aerodynamic heating, the following methods have been used:

(1) Heating with hot gases.
(2) Electrical resistance heating.
(3) Radio frequency induction heating.
(4) Electric blankets.
(5) Solar radiation.
(6) Hot body radiation.
(7) Wind-tunnel testing.
(8) Free flight.

Hot Gases

The use of hot gases for heating can be twofold—namely, heating the material and simulating the effects of oxidation and erosion. The latter effect requires that the oxygen content be of the same proportion as that in the atmosphere and that the gas be moving at high velocity.

A device to produce these effects—known as an "Aeroder"—is shown in Fig. 3. This instrument consists of a jet-engine combustion chamber which is supplied with air from an auxiliary air supply. In addition to the pound of air at 90 lbs./in.² supplied to the combustion chamber, an additional 0.17 lb. of pure oxygen is injected each second so as to maintain atmospheric oxygen content at the expansion nozzle. The test specimen is exposed to this jet at the nozzle opening. The jet over the specimen is between 1,800°–2,000°F. and has a Mach Number of 1.8. By operating the afterburner, temperatures up to 3,500°F. are possible.

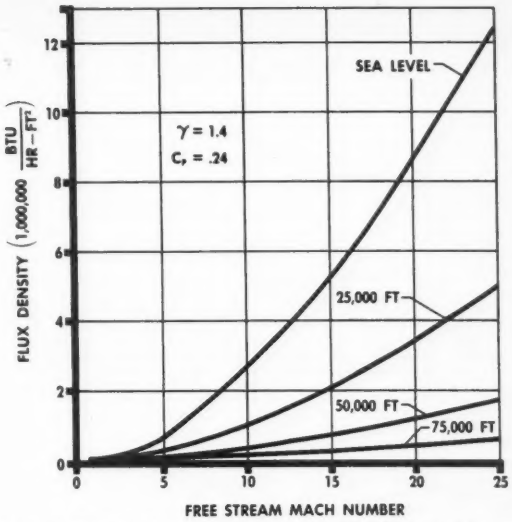


FIG. 2. Variation of maximum heat flux with Mach Number and altitude for a 20° cone.

This installation can handle a test sample about 1 in. wide. The angle of attack of the specimen relative to the jet is adjustable also.

Similar devices using modified rocket motors and burning kerosene with hydrogen peroxide as the oxidizer have been operated successfully. By running "peroxide rich," the jet's oxygen content can be kept close to that of the normal atmosphere. These devices, not limited by the auxiliary air supply capacity, can be built in sizes to accommodate much larger specimens than the Aeroder.

Fig. 4 shows another test arrangement using hot gases as a heat source. This heat tunnel was fired by a large butane burner and was so arranged that the hot gases passed through the specimen directly. The maximum temperature rise on the 0.020-in. aluminum cylinder was 10°F./sec. This represents the comparatively modest flux of 2,300 B.t.u./ft.²/hour.

Fig. 5 shows another configuration used to test a missile fin at elevated temperature. The five oxy-acetylene torches shown are of the "preheat" variety and have a 1-in. diameter nozzle. This system was capable of producing a flux to the specimen of about 75,000 B.t.u./ft.²/hour. This flux, though about twice as great as that employed in modern boiler practice, is considered modest in the light of the requirements shown in Fig. 2, even though it set off the laboratory's sprinkler system 30 sec. after the torches were first lit.

Probably some increase in flux could have been attained by use of some form of regeneration, but even so, the highest temperature part of the oxy-acetylene flame represents only the stagnation temperature corresponding to a Mach Number of about 9 at sea level.

Electrical Resistance Heating

Electrical resistance heating where the current is passed directly through the part is more or less confined to the testing of specimens whose cross section is

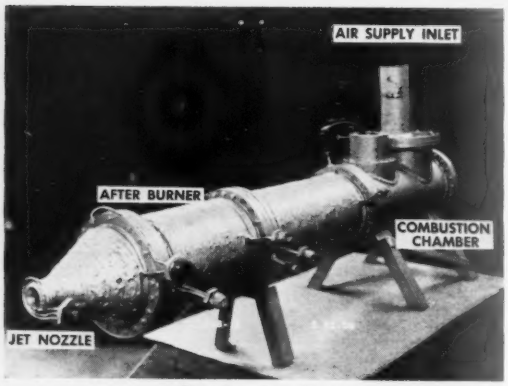


FIG. 3. Aeroder.

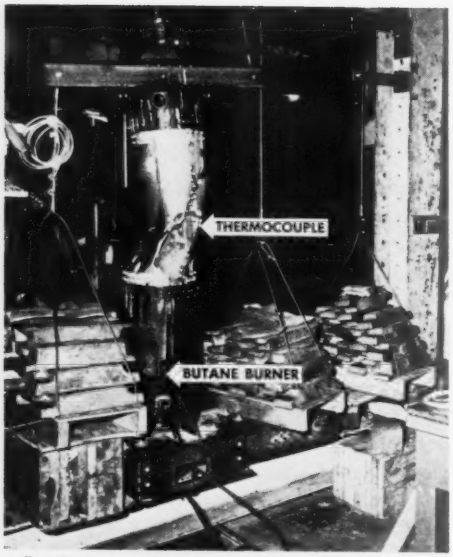


FIG. 4. Specimen tested in shear and bending at elevated temperature.

FIG. 5. Heat tunnel using oxy-acetylene torches as a heat source.

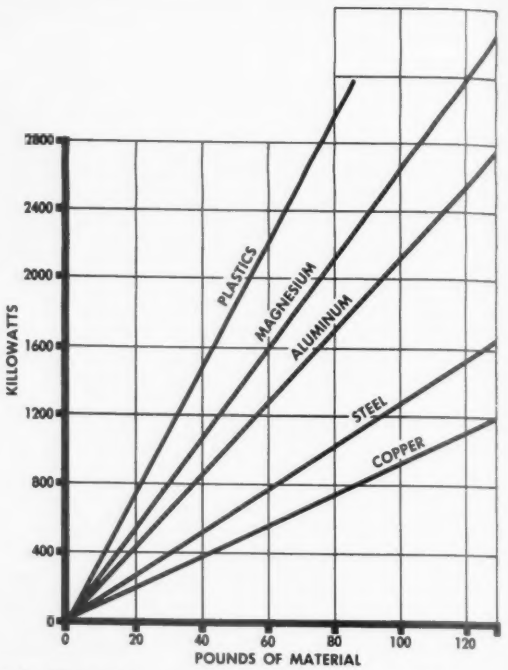


FIG. 6. Thermal power necessary to impart a temperature rise of 100°F. per sec. to various materials.

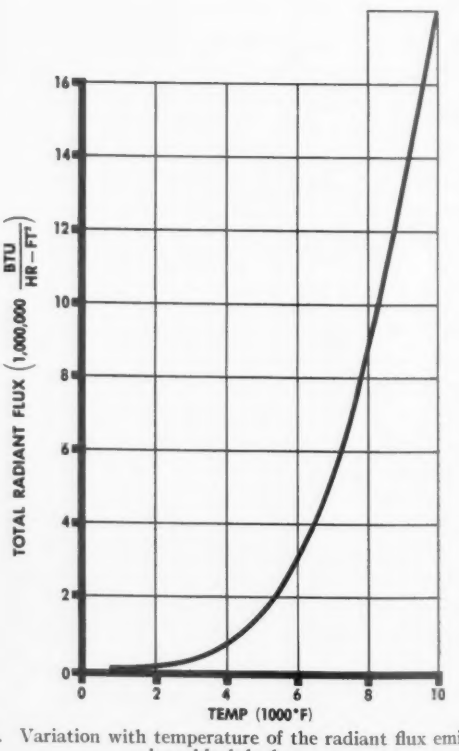


FIG. 7. Variation with temperature of the radiant flux emitted by a black body.

uniform and not of large area, otherwise the current requirements become excessive.

This type of heating lends itself best to small tensile or creep specimens. Actually, there is practically no limit to the rate of temperature rise obtainable by this method of heating—it depends only on the internal resistance of the material and the voltage applied.

Radio Frequency Heating

Radio frequency induction heating lends itself to rapid heating of reasonable size specimens of uniform material. This method approximates aerodynamic heating closely, since the heating takes place on the outer surface, but it has the disadvantage that dissimilar materials will heat at different rates. In other words, an aluminum specimen cannot be fabricated with steel bolts since the bolts may melt before the aluminum reaches its desired temperature. Fig. 6 shows the power requirements necessary for heating a given weight of material. Obviously, the power requirement limits it to small sizes if rapid heating is desired.

Electric Blankets

An electric blanket, as a heating source, relies on conduction for heating. This type of heater is quite flexible and adaptable to irregular shapes. Its use, however, is confined to applications requiring slow heating, though large areas may be covered. Practical heating fluxes for this type of heater are of the order of 500–1,000 B.t.u./ft.^{2}/hour.

Solar Radiation

Maximum direct solar radiation amounts to only about 420 B.t.u./ft.^{2}/hour, which is not a large quantity. However, concentrated by a parabolic mirror, as in a solar furnace, heat fluxes of the order of 2–5,000,000 B.t.u./ft.^{2}/hour can be obtained, depending on the quality of the mirror—the higher value representing the best quality mirror and ideal atmospheric conditions. This represents just about the maximum heat flux available today.

Though this represents a large heat flux, unfortunately, the sun subtends only a 32′ angle in the sky which results in a focal spot of about one hundredth the focal length of the mirror. Thus, a mirror with a 24-in. focal length would provide only a 1/4-in. diameter focal spot.

Even though the focal or heating spot is small, this device is nevertheless useful in evaluating material properties such as melting point, resistance to thermal shocks, and uses in general where an extremely high flux is necessary and small size samples can give the desired results.

A good mirror can provide a black body equilibrium temperature of from 5,000–7,000°F., a temperature which is rather difficult to produce by any other means. Another distinct advantage of this type of heating is that the atmosphere surrounding the specimen can be controlled as desired. The heat from a solar furnace has often been described as a form of pure heat such that a specimen placed within a transparent container can be heated or melted within a controlled atmosphere without contamination from the heat sources.

Hot Body Radiation

Closely allied to the solar furnace are other methods of heating by radiation from high-temperature sources. Fig. 7 is a plot of Stefan-Boltzmann's Law and gives the radiant flux obtainable from a given temperature source.

Several methods of using this principle to simulate aerodynamic heating have been used. One method uses a large graphite plate which is electrically heated. This heating is accomplished by passing current directly through the plate itself, using its self-resistance to produce heat. This heating is accomplished within a refractory oven, and in this manner temperatures of 3,500°F. are obtainable. When the plate is withdrawn from its refractory shroud, it faces the test specimen and heats it by radiation. From Fig. 7, this plate should provide a flux up to 420,000 B.t.u./ft.^{2}/hour.

Two such devices have been built at the University of California at Los Angeles. The latest and largest, measuring 2 ft. by 5 ft., is presently being calibrated; while the other unit, somewhat smaller in size, is now in use at the Forest Products Laboratory, Madison, Wis.

Relatively large specimens can be heated by this method, and rapid temperature rises are obtainable. These plates require a long heating period (a matter of hours) such that the power requirement is not excessive, and a specimen on each side of the plate can be irradiated simultaneously.

A similar method—a little more flexible in its application—uses graphite rods, which are heated to incandescence by passing a large electrical current through them. These rods obviously do not have the flux density of the solid plate, and the number that can be used simultaneously is limited by the power available.

An even more attractive device of this type is a tubular quartz lamp with tungsten filaments produced by the General Electric Company. While normally rated at 1 kw., these lamps may be overloaded up to 3 kw. with acceptable life. The filament temperature attained is 3,500°F. when operated in this manner. An installation, employing these lamps for heating a small fin, is shown in Fig. 8.

These lamps make quite a satisfactory installation from the standpoint of both flexibility of application and control. Since little heat is stored in the filament, by control of the current, the heat flux can be varied as desired, even programed.

Wind-Tunnel Heating

While some small amount of research on structure has been done in wind tunnels, this form of testing does not lend itself well to installations of the type available today. *First*, the power requirements required to heat by this method are even more prohibitive than by the

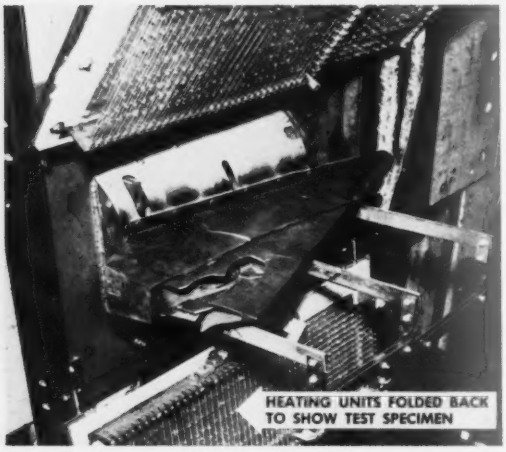


FIG. 8. Fin test arrangement using quartz lamps for heating.

other methods outlined. *Second*, failure of a structure in an air stream with high enough velocity to produce aerodynamic heating could cause severe damage and delay the use of an expensive installation.

Free Flight Testing

Free flight testing is probably the one feasible way of attaining the heat flux associated with flight at the higher Mach Numbers. This technique would use a high-performance rocket or series of rockets to which the structural unit to be tested is attached. These test vehicles could be multistage devices, with the final stage even programed to be fired vertically downward, thus achieving high Mach Numbers at high dynamic pressures.

This type of testing is expensive and requires large operational ranges and large quantities of instrumentation. Also, load simulation is difficult to accomplish.

All these difficulties notwithstanding, this method of structural testing will be used more and more as time goes on and missile velocities increase.

LOADINGS

Up to this point, we have spoken only of the problem of simulating time-temperature effects on a structure. Equally important is the application of the time-load cycle.

Fig. 9[1] shows a typical creep curve for Type 410 stainless steel at 1,500°F. If the limiting factor is deflection, the designer can use 14,000 lbs./in.^{2} if the load is to be applied only 10 sec. and the tolerable deflection is 2 per cent. On the other hand, if the same deflection tolerance is necessary and the load is applied for 2 min., the design stress would have to be lowered to 5,000 lbs./sq.in.—almost a 300 per cent decrease in the working allowable.

Referring back to Fig. 9—should the load remain on for more than 10 sec. at the 14,000 lbs./in.^{2} level, by 13 sec. the deflection will reach 5 per cent, and, if allowed to remain at this level for just over 20 sec., rupture will occur.

The advantages of designing to these higher strengths based on time-of-application-of-load are obvious. Similarly, the test engineer cannot violate this time-load history used in the design or excessive deflections, or even premature rupture of the structure can occur. These time increments are different for each temperature or material, but the implications are plain.

In the face of these facts it is clearly indicated that loading and data recording must be closely programed and in all probability automatically applied.

Fig. 10[2] shows the effects of strain rate on the ultimate strength of 2014-T6 aluminum alloy. Obviously, the designer will have taken advantage of the increase in strength where rapid loadings are involved. Here again, the test engineer must simulate the loading cycle precisely if the test is to have meaning.

In many cases it has been found that hydraulically operated loading mechanisms are inadequate, and pneumatic or hydropneumatic methods have had to be adapted to supply the necessary speed in loading.

CONCLUSION

The problem of simulation of the loads and heating experienced by a hypersonic vehicle is one of enormous proportion. Even the best sources presently available, disregarding the size of the specimen they can handle,

(*Continued on page 75*)

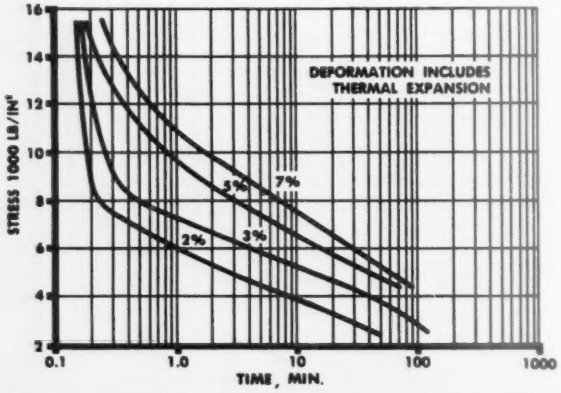


FIG. 9. Time-deformation curves for Type 410 stainless steel at 1,500°F.

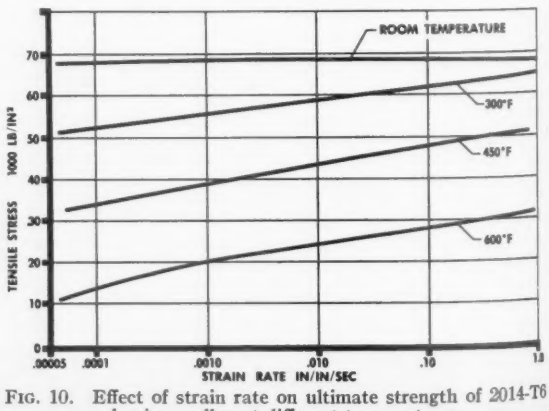


FIG. 10. Effect of strain rate on ultimate strength of 2014-T6 aluminum alloy at different temperatures.

Norris F. Dow*
General Electric Company

A Re-Evaluation of Some Air-Frame Thermal Problems

A second approximation of the significance of the problems of material selection, thermal stresses, and inelasticity or creep encountered in the air frame in supersonic flight. The conclusion is reached that, in the area of gross thermal effects on the structure, material and structural advances should keep pace with those in the fields of aerodynamics and propulsion so that progress will not be slowed by the thermal barrier.

Introduction

THE THERMAL PROBLEMS encountered by the air frame in supersonic flight fall into three general categories: (1) material selection, (2) thermal stresses, and (3) inelasticity or creep. These problems have been thoroughly delineated in papers by Steinbacher and Young,[1] Hoff,[2] Heldenfels,[3] and others.[4, 5] As is proper in such surveys, first-order approximations have been made in order to assess the magnitude of the problems. The intent of the present paper is to take a second look at some of these problems to determine whether second-order effects appreciably alter the general conclusions in some ranges and whether possible approaches exist leading toward the alleviation of the problems.

Material Selection

As pointed out by Heimerl and others (see, for example, reference 6), proper selection of material to enable the air frame to withstand the temperatures of Mach 3 or 4 flight requires more than a knowledge of strength-to-weight ratios.[7] Because of the possibility of buckling in compression, for example, materials which withstand elevated temperatures better than the light alloys, such as titanium and steel, achieve low values of buckling stress-density ratios as a result of their high densities. The conventional measure of plate-buckling efficiency—namely, a plot of buckling stress-density ratio against the structural index (intensity of loading divided by plate width, Fig. 1)—appears at first glance to point up the low efficiency associated with the heavier material. Thus, for example, even at temperatures as high as 500°F. where the aluminum alloys are normally considered of limited effectiveness and even at the higher values of the plate structural index where high-density materials usually show up to their best advantage, solid steel plate still achieves lower values of the buckling stress-density ratio than aluminum alloy (Fig. 1).

A simple comparison of this nature, however, is unrealistic to the extent that designers have realized for some time that the efficiency of compression members which are liable to buckle can be raised by adding supporting members or stiffeners to prevent buckling. This is conveniently done with steel by utilizing a sandwich type of construction,[10] and the efficiency of such a sandwich even at elevated temperature compares favorably with that for the lighter alloys at room temperatures (Fig. 2).

There is a general conclusion to be drawn here—namely, that material selection based on such first-order approximations as comparisons on the basis of material plate-buckling structural indices or even more complex structural indices such as that proposed by Gordon and Jackson[8] may be misleading. Cognizance needs to be taken of appropriate ways of utilizing the material in the structure, and then the comparisons may be made on the basis of the material utilized in an optimum manner. (This point is made convincingly in reference 9). Thus, for example, high-strength steel sandwiches offer promise of withstanding temperatures as high as 600°F. without a substantial weight penalty compared to room temperature aluminum-alloy structures (Fig. 2), although, on a simple plate efficiency basis, the aluminum would have been substantially lighter. In other words, on the basis of utilization in optimum structural form, high-temperature materials may be found to be not so inefficient as indicated by first-order approximations.

The selection of materials for supersonic missile air frames requires a somewhat different approach from that used for the low supersonic regime. Rate of heating must be considered, as well as maximum temperatures.

Presented at the Aerodynamic Heating: Structural Aspects Session, National Summer Meeting, IAS, Los Angeles, June 18–21, 1956.

* Structures Engineer, Special Defense Projects Department.

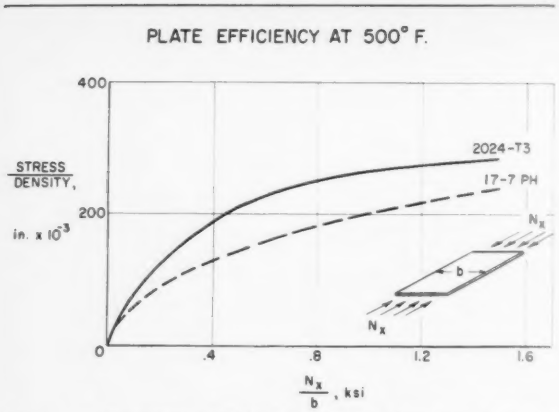


FIG. 1. Plate strength efficiency of 2024-T3 aluminum alloy and 17-7 PH stainless steel at 500°F.

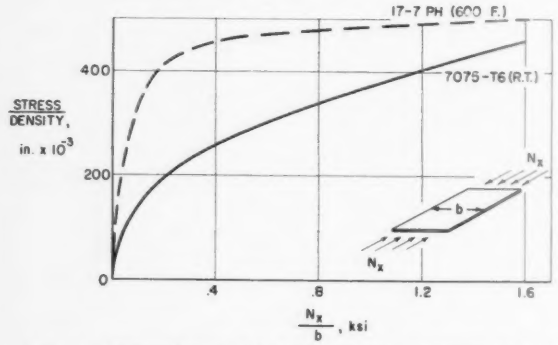


FIG. 2. Comparison of the plate strength efficiency of 17-7 PH sandwich at 600°F. and 7075-T6 aluminum-alloy plate at room temperature.[10]

Also in cases in which the heating is of short duration, one function of the skin material may be to act as a heat sink; hence the material may need to be selected in part on the basis of its ability to stay below some critical temperature.

In order to evaluate the nature of this problem, let us suppose that the critical temperature is the melting point of the material and that the heating rate corresponds to the order of magnitude given by Duberg[5] for a suddenly attained Mach Number of 10 at an altitude of 50,000 ft.—namely, slightly less than 100 B.t.u. per sq.ft. per sec. (Fig. 3). Under conditions of severe transient heating such as these, materials may be divided into two classes for the evaluation of their heat-sink characteristics:

(1) Those of sufficient thermal conductivity so that the entire thickness of material is effective in absorbing heat.

(2) Those of lower conductivity or requiring greater thickness so that the heat does not penetrate substantially below the surface.

The quantities which determine whether a material falls into the first or the second class are those included in the parameter found by assuming a square-wave heat pulse and solving the one-dimensional heat-conduction problem. This parameter is $k\tau/cwt^2$ where

k = thermal conductivity, B.t.u./ft.-sec.-°F.
τ = time, sec.
c = specific heat, B.t.u./lb.
w = density, lb./ft.^{3}
t = material thickness, ft.

For values of this parameter less than approximately 0.5, the high temperature has not penetrated appreciably below the inside surface of the material by the time the heat pulse is over. Thus, in this case, heat-sink capacity is a function of the thermal conductivity for a given length of heat pulse since the greater the conductivity the greater the depth that the heat will be absorbed into the material. Hence the value of copper as a heat-sink material despite its poor structural properties.

Of perhaps greater significance is the fact that, for values of the parameter $k\tau/cwt^2$ greater than about 3, the thermal gradient through the thickness of the material is becoming of negligible magnitude. Here the material is therefore essentially fully effective as a heat sink; the thermal stresses due to the thermal gradient are not important; and, in short, the material is being much more effectively utilized than for small values of the parameter. Hence, attaining effectively large values of $k\tau/cwt^2$ becomes a desirable engineering objective. For a heat pulse duration of 30 sec., for example, the thicknesses of various materials such that $k\tau/cwt^2 = 3$ are

Aluminum alloy	2024-T3	0.87 in.
Stainless steel	17-7 PH	0.27 in.
Titanium alloy	RC-130A	0.27 in.

Assuming a square-wave heat pulse—that is, instantaneous acceleration to the full assumed speed of Mach 10 at 50,000 ft., even neglecting both radiation and decreasing heat input with rising skin temperatures—all of these materials will absorb the full heat pulse without melting and hence are adequate as heat sinks if adequate material is also provided for structural strength.

The conclusion to be drawn is that, for moderate hypersonic speeds and flight durations, conventional structural materials may be utilized as heat sinks, and the selection of the proper one to use depends upon other characteristics than thermal conductivity. For example, to absorb the 3,000 B.t.u./ft.^{2} heat pulse used for this illustration by raising the temperature of the material from the −100°F. environment at 50,000 ft. to the melting point, the approximate weights of the three materials considered required are

2024-T3	11.2 lbs./ft.^{2}
17-7 PH	10.0 lbs./ft.^{2}
RC-130A	7.2 lbs./ft.^{2}

On this simplified basis, then, the use of titanium as a heat sink permits more poundage to be left over for structural purposes.

Before leaving the discussion of materials for heat-sink applications, let us consider what potential there is

for improvement in the range for which the nonmelting heat sink is practicable. As some indication of the potential, there is the familiarly peculiar metal beryllium[11] which has both a high specific heat and a high melting point. Beryllium is fully effective up to 0.8-in. thickness for 30-sec. heat pulses and requires a weight of only 2.5 lbs./ft.^{2} to absorb 3,000 B.t.u./ft.^{2} of heat or approximately 1/4 the weight of stainless steel. This does not mean that beryllium is recommended for use; its scarcity and toxicity are well known. The potential is there, however, presenting a challenge to materials engineers to find substitute materials which are as good or to find ways of utilizing that potential.

Despite potential improvement such as that permitted by beryllium, the range of application of the nonmelting heat sink is definitely limited. For values of $k\tau/cwt^2 < 0.5$, it is evident that there is some maximum heat pulse for each material beyond which melting of the material at its external surface cannot be avoided no matter how great the thickness of material used. Here is a real thermal barrier which cannot be overcome by any nonmelting, heat-sink approach. Therefore, for heat pulses greater than these limiting values, some other solution than the nonmelting heat sink must be found.

Thermal Stresses

The effects of thermal stresses induced by the temperature gradients arising during accelerated supersonic flight can be divided into several categories: (1) loss of stiffness—or structural instability problems caused by thermal stresses, (2) loss of strength because of high thermal stresses, and (3) structural inadequacy due to the high thermal stresses themselves. Totally apart from the fact that in many cases thermal-stress-alleviating-type structures may be used to avoid the thermal-stress problem—that is, corrugated or pin-jointed members may be used in place of straight, solid members to permit unrestrained thermal expansion and contraction—there are a number of these "problems" which at second glance appear to be to some extent self-alleviating.

Loss of Stiffness

The interesting problem considered by Budiansky and Mayers[12] is a typical example of loss-of-stiffness associated with thermal stresses. They considered a solid steel double-wedge airfoil section instantaneously accelerated to a supersonic Mach Number and calculated the loss in twisting stiffness for such a section caused by the compressive thermal stresses induced at the leading and trailing edges of the section. The resulting ratio of twisting stiffness to initial twisting stiffness, as given by reference 5, is shown in Fig. 4.

Examination of the assumptions leading to the result calculated here suggests that almost all of the factors present in an actual wing and differing from those assumed are in the direction of reducing the loss in stiffness. The airfoil analyzed was assumed to be of infinite length and constant cross section, instantaneously accelerated, and of infinite thermal conductivity through the thickness but of zero conductivity chordwise. Quite apart from stress-alleviating dodges to which the designer might and should resort—such as slitting the leading and trailing edges and, particularly, making the section hollow thus effectively eliminating the stiffness reduction[12]—we find that for low aspect ratio sections the reduction is less, for a taper in plan form the reduction is less, and for a gradually accelerated section of moderate chordwise thermal conductivity the reduction is less. (See Fig. 5.)

Inclusion of chordwise thermal conductivity complicates the analysis, and an accurate evaluation of this effect is beyond the scope of this paper. Rough approximation of the heat fluxes existing at various stages of heating, however, suggests an approximate 10–15 per cent further reduction in maximum thermal stress for the steel section if the rate of acceleration is 32 ft./sec.^{2} rather than infinite. This reduction is in addition to the reduction for finite acceleration calculated by Budiansky and Mayers. Taper in plan form with spanwise conductivity produces still further reduction. Even the minor constructional details of a practical amount of blunting of the leading and trailing edges produces a not insignificant alleviation of the loss of

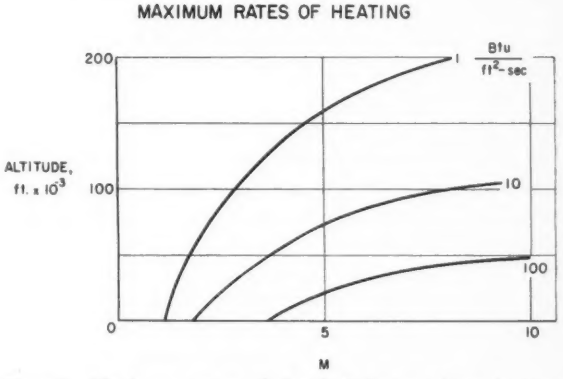


FIG. 3. Maximum rates of heating[5] for an instantaneous acceleration to a given Mach Number at a fixed altitude.

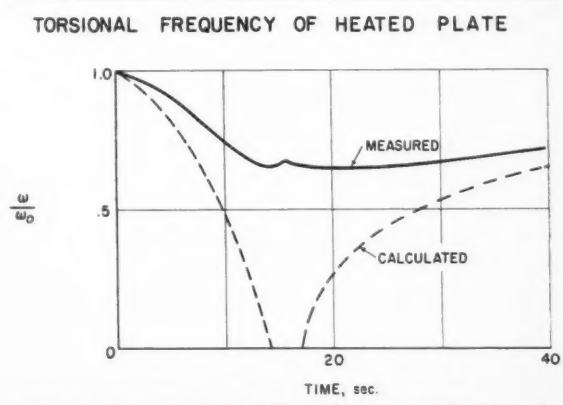


FIG. 4. Loss of twisting stiffness (as measured by decreasing natural frequency) calculated and measured for a rectangular plate with heated leading and trailing edges.[5]

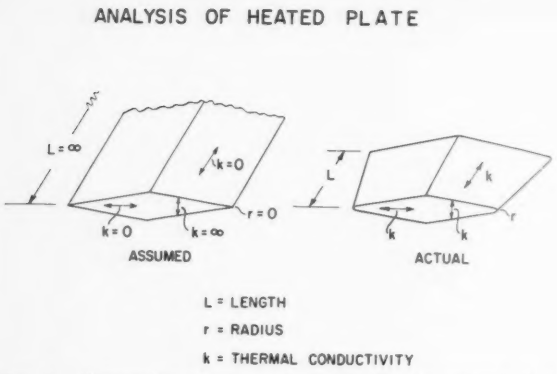


FIG. 5. Illustration of assumptions made in the analysis of a solid, double-wedge section.[12]

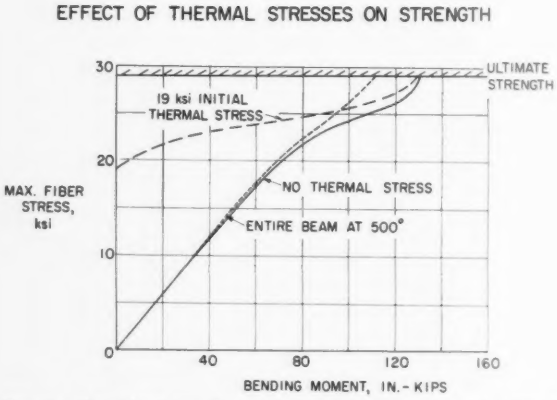


FIG. 6. Combined bending and thermal stresses in a simplified model of a beam.

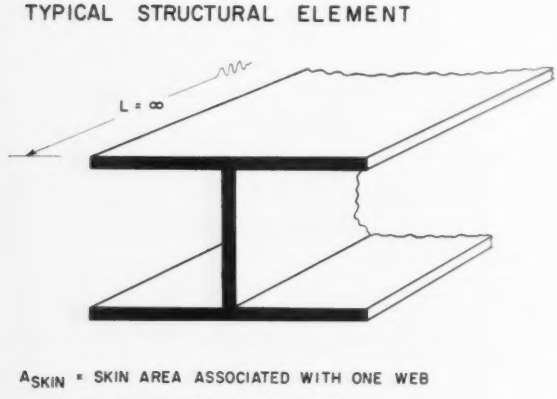


FIG. 7. Structural element typical of analyses for thermal stresses.

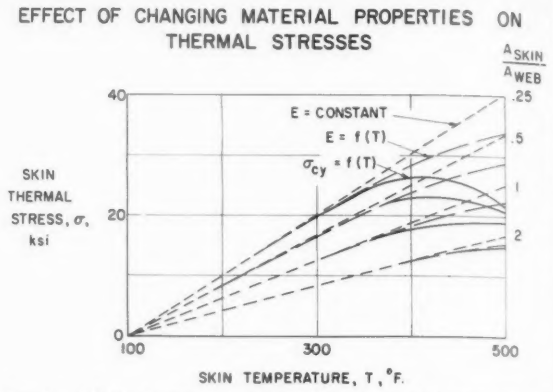


FIG. 8. Effect of temperature variation of material properties on thermal stresses for 2024-T3 aluminum alloy.

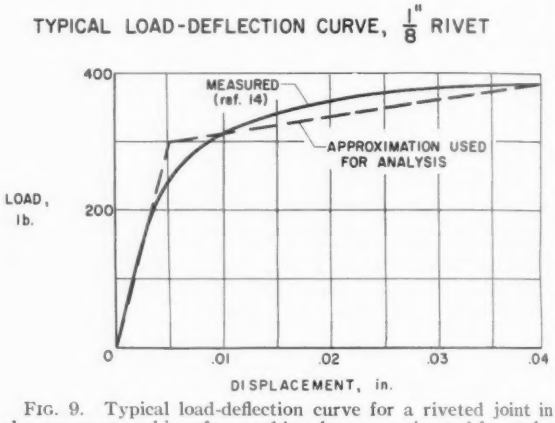


FIG. 9. Typical load-deflection curve for a riveted joint in shear as measured in reference 14 and as approximated for analysis in the present paper.

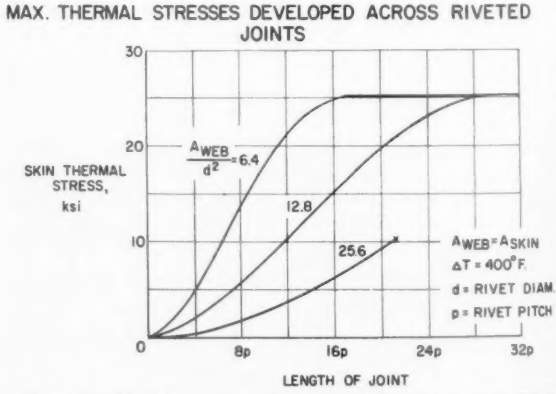


FIG. 10. Maximum thermal stresses induced in a simplified, riveted structural element assuming constant, elastic material properties.

stiffness by reducing the amount of material subjected to compressive stresses.

While no quantitative evaluation of the sum of the alleviating effects enumerated has been made, it is clear that the loss of stiffness of a simplified model such as considered by Budiansky and Mayers is conservative and valuable particularly as a warning to the designer. Once warned, however, the designer should be able to take advantage of suitable alleviating factors to avoid the problem without a serious penalty.

Loss of Strength

In the previous section in which loss of stiffness was considered, the effect of changing material properties with temperature was neglected, in part because of the simplification provided thereby, in part because there are compensating factors which tend to make the material property changes of lesser importance for stiffness problems than for strength.

The changes in material properties with temperature do affect the ultimate strength, of course, but this effect is not compounded directly by the addition of thermal stresses. Indeed, it can readily be shown by the use of a simple model that thermal stresses may have no real effect on ultimate strength at all.

In Fig. 6 are shown the results of an analysis of the bending of a simple model of a beam of 2024-T4 aluminum alloy having its outside fibers at 500°F. The effects of the high thermal stresses are lost by the time the bending moment has been increased to about two thirds of the ultimate, and the bending strength of the beam with thermal stresses is greater than that for a beam without thermal stresses and having its entire cross section at 500°F. The strength for a beam with the same thermal gradient as required to produce the thermal stresses but having some alleviating device so that no thermal stresses are produced is only negligibly greater than for no thermal stress alleviation.

The general conclusion that, for ductile materials, thermal stresses may not have a profound effect on overall ultimate strength may be drawn—with reservations, as will be shown.

Structural Inadequacy Due to Thermal Stresses

Obviously, if the thermal stresses alone are high enough to cause structural failure, they have an influence on ultimate strength, and one logically inquires, "Is this situation likely or unlikely to occur?"

The analysis of the thermal stresses induced in a "typical structural element" (Fig. 7) is a popular one, and contributions to it have been made by a number of authors (see, for example, reference 13). The usual assumptions are that the material is elastic and of constant, uniform properties and that the section is integral. While these assumptions are appropriate for preliminary considerations at low temperatures and stresses, they bear little resemblance to reality as the temperatures and stresses go up.

Consider, for example, the thermal stresses induced in the skin of an element such as that shown in Fig. 7 of 2024-T4 aluminum alloy under conditions such that the average temperature in the web is 100°F. and the average temperature in the skin varies up to 500°F. The dotted curves in Fig. 8 represent the skin thermal stresses calculated on the assumption of constant, elastic material properties, the various curves being for various ratios of cross-sectional area in the skin to cross-sectional area in the web. The light dashed curves show the effect of taking into account the variation in Young's modulus with temperature, and the solid curves give the combined effects of changing modulus and plasticity with temperature. Evidently there is some temperature at which a maximum thermal stress is produced, and this maximum is well below the ultimate strength of the material at that temperature.

An additional source of possible thermal stress alleviation compared to the simple model of Fig. 7 arises if the structure is riveted together rather than made of one integral piece. Riveted joints are not rigid[14]; typical load-deflection curves for rivet joints indicate that appreciable slippage can occur before the rivet fails (Fig. 9). The magnitude of the reduction in thermal stress because of rivet slippage, however, does not turn out to be of great significance.

With the use of two straight lines to approximate the rivet load-deflection curve and on the assumption that material properties do not change with temperature, an analysis was made of the thermal stresses developed by a temperature differential of 400°F. across a riveted "typical structural element" of the type illustrated in Fig. 7. As Fig. 10 shows, this analysis reveals that the thermal stresses build up rapidly as the length of riveted joint increases, provided that the rivet diameter is reasonably large compared to the area of material being joined. If small diameter rivets are used to join heavy sections, however, the thermal stresses will fail the rivets. These rivet failures can occur at low thermal stresses—low enough so that they will not be appreciably alleviated by plasticity, and one is led to the conclusion that, although there are powerful alleviating factors which tend to decrease the engineering significance of thermal stresses, still they may be of substantial importance in detail design, such as the design of riveted joints.

Inelasticity or Creep

Review of the factors involved in the determination of the significance of the creep problem in supersonic flight leads inescapably to the conclusion that creep as such is of importance only in special, particular instances. As pointed out by Heldenfels,[3] aircraft experience loads only intermittently and high loads for only a small fraction of their lifetime. By the same token, the history of experience of simultanous maximum loads and temperatures in an aircraft structure is a rather far cry from the constant high load at elevated temperature normally considered in creep analysis.

Even if loads and high temperatures are encountered together for long times, creep to some extent tends to alleviate itself: As pointed out by Hoff,[2] creep tends to diminish the stresses in the areas of greatest stress concentration, and as shown by Steinbacher and Young,[1] creep tends to load up the cool parts of the structure and unload the hot ones. All of these surveys, therefore, seem inclined to minimize the significance of creep.

Because of the intermittent, repetitive nature of aircraft loads, however, inelasticity or creep can be a serious problem—just how serious depending upon the nature of the flight history under consideration. This problem, delineated some time ago by Freudenthal[15] and Parkes,[16] must be particularly borne in mind for aircraft having appreciable thermal inertia and high rates of acceleration and deceleration.

For example, consider a vehicle for which the flight history illustrated in Fig. 11 is repeatedly encountered—namely, a rapid acceleration to supersonic speed, a high-speed run, and a rapid deceleration to low speed again. The first portion of this flight induces a high temperature in the skin and corresponding thermal stresses between skin and internal supporting structure. For the purpose of this illustration, the assumption is made that the temperatures, stresses, and times involved are great enough so that some compressive creep or yielding occurs in the skin. In consequence of this creep, when the temperature difference has had time to equalize itself between skin and internal structure, a residual tension is left in the skin and a residual compression is left in the internal member (Fig. 11). If now the aircraft is decelerated rapidly so that the skin is cooled, setting up the same sort of temperature differential (see reference 17) as on acceleration but of opposite sign, a somewhat greater compressive thermal stress is induced in the internal member than was in the skin by superposition on the residual stress. The greater stress produces more creep and leaves a residual compression in the skin after the flight is over. This process is repeated on subsequent flights, and thus greater and greater residual stresses may be accumulated until failure occurs.

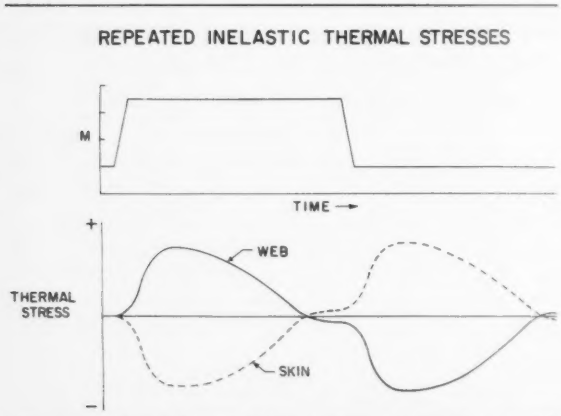


FIG. 11. History of cyclic thermal stresses, showing a possible accumulative effect of creep or plasticity.

Clearly, the illustration given is an idealized one, chosen to be as simple as possible. There are many complicating factors which can be introduced to change the resulting stresses, and the chief point to be made is that the potential exists for the growth of thermal stresses because of inelastic behavior of the material. Qualitatively, inelasticity due to creep appears possibly more dangerous than that due to a plastic yielding such that strain-hardening characteristics may help the material to accommodate itself to the cyclic conditions. The problem merits experimental study. Particularly it must not be ignored in the analysis of anticipated lifetimes of interceptor-type aircraft.

CONCLUSION

The state of the art of design of air frames for high-temperature environments has advanced in the past few years to the point that the major problems have been defined at least to the extent of a first approximation. The second approximation to many of these problems yields a somewhat less dismal outlook. More nearly optimum utilization of material, as in steel sandwiches, can reduce the weight penalties associated with the lower Mach Numbers. Development of better heat-sink materials may make possible improvements in hypersonic vehicles subjected to short heat pulses. Thermal stresses and creep still require consideration, but to some extent at least this may be more in the area of detail design than in the area of gross effects on the structure. As a whole, there is reason for optimism that structural and material advances will keep pace with those in the fields of aerodynamics and propulsion so that continued progress will not be appreciably slowed by the thermal barrier.

REFERENCES

[1] Steinbacher, F. R., and Young, Louis, *Problems in the Design of Aircraft Subjected to High Temperatures*, ASME Trans., Vol. 77, No. 5, July, 1955.

[2] Hoff, N. J., *The Thermal Barrier—Structures*, ASME Trans., Vol. 77, No. 5, July, 1955.

[3] Heldenfels, Richard R., *Some Elevated Temperature Structural Problems of High-Speed Aircraft*, SAE Preprint No. 599, for presentation at the SAE Golden Anniversary Aeronautic Meeting, Los Angeles, October, 1955.

[4] Horton, W. H., *The Influence of Kinetic Heating on the Design and Testing of Aircraft Structures*, presented to Centennial Celebrations Symposium, Polytechnic Institute of Brooklyn, 1955.

[5] Duberg, John E., *Aircraft Structures Research at Elevated Temperatures*, presented to Structures and Materials Panel of AGARD (NATO), London, England, September, 1955.

[6] Heimerl, George J., and Hughes, Philip J., *Structural Efficiencies of Various Aluminum, Titanium, and Steel Alloys at Elevated Temperature*, NACA TN 2975, July, 1953.

[7] Dix, E. H., Jr., *Aluminum Alloys for Elevated Temperature Service*, Aeronautical Engineering Review, Vol. 15, No. 1, pp. 40–48, 57, January, 1956.

[8] Gordon, S., and Jackson, L. R., *The Application of a New Structural Index to Compare Titanium Alloys with other Materials in Airframe Structures*, Preprint No. 56-AV-11, presented at the ASME Aviation Conference, Los Angeles, March, 1956.

[9] Schnitt, Arthur, Brull, Maurice A., and Wolko, Howard S., *Optimum Stresses of Structural Elements at Elevated Temperatures*,

(*Continued on page 85*)

Harry Drell* and Thomas A. Sedgwick†
Lockheed Aircraft Corporation

Induction System Selection

A comparison of internal and external compression supersonic induction systems.

Symbols

A_C	= inlet capture area, ft.²
A_F	= frontal area of installation, ft.²
$A_P = (A_F - A_C)$	= cowl projected area, ft.²
$C_D = D/q_0A_F$	= cowl drag coefficient based on frontal area
$C_{D_P} = D/q_0A_P$	= cowl drag coefficient based on cowl projected area
$C_F = F/q_0A_F$	= thrust coefficient
D	= cowl pressure drag force, lbs.
F	= engine net thrust, lbs.
$(F - D)$	= propulsive thrust, lbs.
H	= total pressure, lbs./ft.²
(H_3/H_0)	= total pressure recovery
K	= ratio of cowl drag of an axially symmetric cowl to that of a two-dimensional cowl
M	= Mach Number
$q = (1/2)\ \rho V^2$	= velocity head, lbs./ft.²
$SFC = W_f/(F - D)$	= specific fuel consumption, (lbs./hour)/lbs.
$SFC_{isen} = W_f/F$	= specific fuel consumption for 100 per cent recovery and zero drag
V	= velocity, ft./sec.
W_f	= engine fuel flow, lbs./hour
β	= duct loss coefficient
ρ	= density, slugs ft.³
θ_L	= cowl external lip angle, deg.

Subscripts

0	= free stream
1	= upstream of inlet normal shock
2	= downstream of inlet normal shock
3	= engine compressor inlet
isen	= isentropic (100 per cent total pressure recovery)

Introduction

Of the many problems facing the aircraft designer, one which has undergone a major change in relative complexity is that of induction system design for the propulsion units. When, in recent years, airplanes started to brush against the sonic barrier and then broke through, it became apparent that efforts expended in achieving improvements in ram recovery yielded performance gains just as significant as those possible from equal effort spent toward body or wing drag reduction. As aircraft continue to advance in speed up to Mach 3 and beyond and are required to fly at higher and higher altitudes, the need for obtaining maximum ram recovery will become even more significant.

A second facet of the induction system problem which must now be carefully re-evaluated in light of the impending higher supersonic speed range is the price in drag which must be paid for achieving improvements in ram recovery. In order to achieve the higher speeds, it is necessary to have larger and larger propulsion units with smaller and smaller wings. As a result, the propulsion unit becomes a larger fraction of the total airplane frontal area and drag. Obviously this portion of the airplane must now receive the same careful scrutiny as the main air-frame body itself. It is the purpose of this paper to examine the various types of induction system and suggest procedures for selecting the optimum design.

Major Types of Engine-Inlet

Two types of inlet shall be considered here, classified according to the method used to obtain compression, and shown in Fig. 1. These are, *first*, external compression inlets available as (a) two-dimensional ram or wedge type and (b) three-dimensional or conical type. *Second* are the internal compression types also available

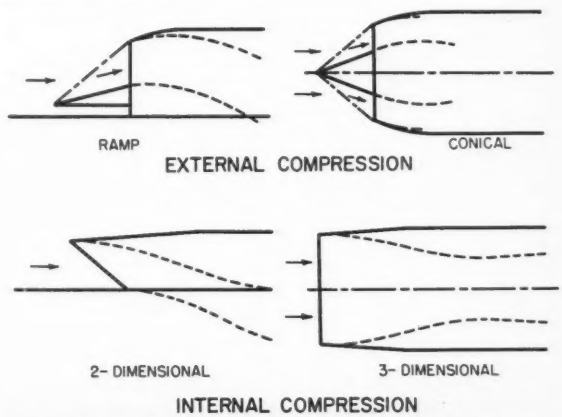


Fig. 1. Internal and external compression inlets.

* Propulsion Department Manager.
† Thermodynamics Engineer.

in two- or three-dimensional configurations. These may be further classified according to the number of shock waves involved in the external compression of the air ranging from two shocks to the isentropic type in the limit.

The external compression inlet is characterized by having all supersonic compression occurring on free external surfaces. The shock down to subsonic speeds may occur on these same surfaces or within the enclosed cowl lip. The significant point is that, to accommodate the deflected flow entering the inlet, the cowl lip internal surfaces must be aligned at the flow deflection angle. Furthermore, the practical problem of turning the airflow back toward the body centerline at a gradual enough rate to avoid separated flow internally requires that the cowl lip be extended outward at the entering flow angle for an appreciable distance. This results in a strong oblique shock wave on the external portion of the cowl with resulting cowl wave drag.

In the internal compression inlet, the flow enters the cowl lips in the free-stream direction, and there is usually sufficient internal shape contraction so that the external portion of the cowl lip can remain aligned in the free-stream direction and still have space for structure. Thus, it may be designed to operate without cowl drag at its design point. Unfortunately, the internal compression inlet has serious operating problems—such as starting supersonic flow, flow stability, and off-design operation—which have led most designers to use the external compression inlet in spite of its drag penalty.

Characteristics of External Compression Inlets

Let us now examine the relative merits of the external compression inlets. First, consider the total pressure recovery available from optimum ramp and conical inlets. The available pressure recovery referred to is that following one oblique and one normal shock wave in inviscid flow and is obtained from standard theoretical shock-wave relations. These are shown in Fig. 2. The results indicate that the optimum conical inlet yields an available pressure recovery on the order of 1 per cent higher than the corresponding optimum ramp type of inlet over the Mach Number range from about

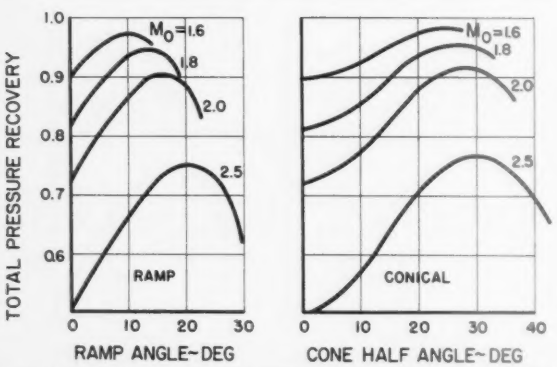


Fig. 2. Optimum pressure recoveries of two-shock external compression inlets.

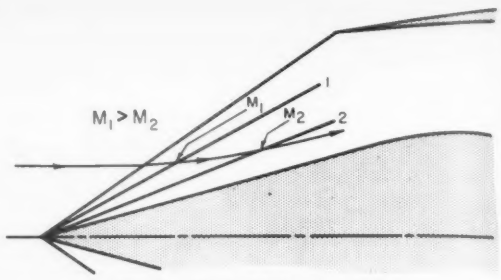


Fig. 3. Conical inlet flow field.

1.6 to 2.5. In reality, the conical inlet has a larger advantage in pressure recovery available than shown here because the Mach Number following the oblique shock on the two-dimensional type is higher than that predicted by the simple two-dimensional flow theory used for obtaining these values. The increase in Mach Number following the oblique shock for the ramp-type inlet of finite width is due to the three-dimensional characteristics of the flow which are introduced by the fact that the sides of the ramp which are parallel to the free stream do not provide any supersonic compression. The higher Mach Number following the oblique wave results in increased total pressure losses through the normal shock. This shortcoming can be overcome to some extent by the use of side plates on the ramp to preserve the two-dimensionality of the flow. The conical type of inlet does not have this problem.

The primary reason that conical inlets offer a higher available total pressure recovery is the fact that the average Mach Number preceding the inlet normal shock is lower for the optimum conical inlet than for the corresponding optimum ramp-type inlet. Fig. 3 pictures the flow field for a conical inlet. Following the compression through the oblique shock, there occurs a significant amount of isentropic compression. Consequently, the Mach Number on the conical compression surface is lower than for the corresponding optimum ramp-type inlet. The magnitude of this difference is shown in Fig. 4. It may be noted that the curves are divided into regions of separated or no-separation flow. Bogdonoff in a Princeton report* has shown that separation of the compression surface boundary layer due to shock interaction is a function of the static pressure ratio across the shock. While there still exist many unknowns on this subject, he presents sufficient evidence to indicate that separation may occur when the static pressure ratio across the normal shock exceeds 1.90. Fig. 4 shows that separation is produced by the optimum two-dimensional surface at $M = 1.88$ and by the conical inlets at $M = 2.0$. Above these speeds, separation of the boundary layer will prevent attainment of theoretical recovery for either inlet. This problem will be discussed in more detail later. The lower surface Mach Number produced by the conical

* Bogdonoff, S. M., and Kepler, C. E., *Separation of a Supersonic Turbulent Boundary Layer*, Princeton University, Report No. 249, January, 1954.

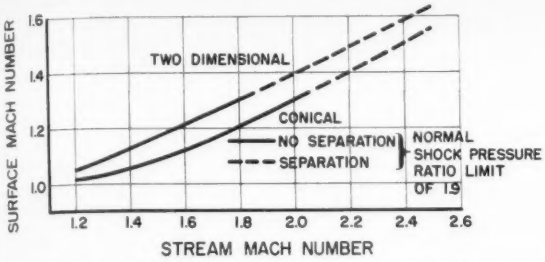


FIG. 4. Surface Mach Number for optimum two-shock external compression inlets.

shock thus results in a double gain. *First*, the total pressure loss through the normal shock is reduced, and *second*, the surface boundary-layer separation is delayed to a higher free-stream Mach Number.

Another interesting property of the conical inlet may be noted in Fig. 2. Whereas it is necessary to use a different ramp angle to obtain optimum recovery at each free-stream Mach Number for the two-dimensional inlet, a fixed conical inlet of from 25° to 28° results in optimum recovery over a broad range of Mach Number. This characteristic of conical inlets is best demonstrated by comparing the theoretical two-shock pressure recovery of a continuously variable angle ramp scheduled to obtain optimum pressure recovery at all Mach Numbers with the theoretical two-shock pressure recovery of a fixed 25° conical inlet as indicated in Fig. 5.

The outstanding advantages of the two-dimensional inlet all lie in the realm of practical application. Because of the smaller physical deflection angle used in a ramp for a given amount of compression, less of a turning angle is required to redirect the air toward the body centerline. For a given capture area, less wetted surface is required for the two-dimensional inlet, and thus the boundary-layer control problem is diminished. Finally, its shape is more readily adapted to providing complete variable geometry than the conical inlet.

The conical inlet appears to offer the advantages of (1) higher available total pressure recovery, (2) lower compression surface Mach Number and consequential minimization of the compression surface boundary-layer separation problem, and (3) broad Mach Number range of high performance enabling the use of a constant geometry inlet. Up to this point, performance has been evaluated only in terms of recovery, and furthermore the discussion has considered only two-shock inlets.

MULTISHOCK INLETS

In general, the number of shock waves required for efficient compression depends on the Mach Number range of operation as illustrated in Fig. 6 wherein the theoretical inviscid pressure recovery of the inlet is indicated for optimized two-dimensional inlets. It should be noted that, when the number of shocks in a system is referred to, this includes a final terminal or normal shock. It is apparent that for Mach Numbers below 1.8 the use of three shocks offers only a small theoretical pressure recovery advantage over a two-shock configuration (and in practice, because of boundary-layer separation, may result in a disadvantage). However, in the region from Mach 2.0 to 2.4, a 5 to 10 per cent gain appears possible with a three-shock system, and further large gains appear available for four- and five-shock systems as the flight Mach Number increases to Mach 3 and then to Mach 4. Indeed, for obtaining maximum pressure recovery, the isentropic or continuously curved compression surface appears attractive at the higher Mach Numbers.

There are serious inherent problems which have prevented the successful use of these multishock external compression inlets to date:

(1) The compression surface boundary layer tends to separate because of the large static pressure gradients and results in large losses in pressure recovery. In the last few years sufficient progress has been made in determining the causes and criteria for boundary-layer separation that new attempts are now being made to use the multishock inlets. Most of these data are classified, but initial results appear promising.

(2) The multishock inlets are extremely sensitive to off-design conditions and thus generate a very severe engine-inlet matching problem. Again, however, a number of solutions to this problem have recently been proposed, and some success has been obtained.

(3) The elements of the third problem are illustrated in Fig. 7.

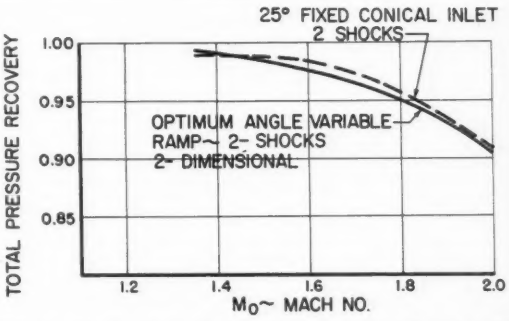


FIG. 5. Comparison of total pressure recoveries of a fixed conical inlet and an optimum variable angle two-dimensional inlet.

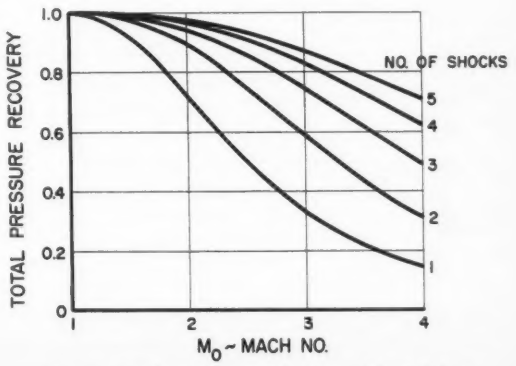


FIG. 6. Optimum recoveries of multishock inlets.

FIG. 7. Family of external compression inlets.

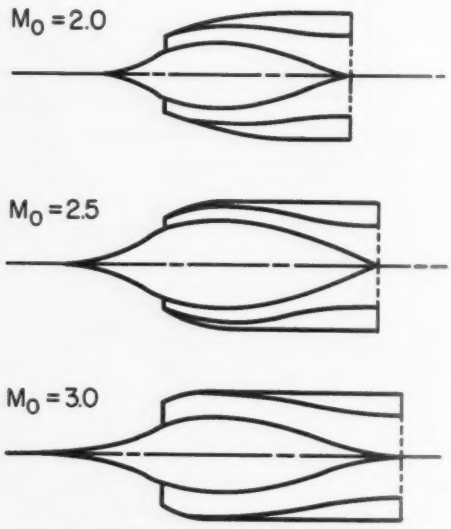


FIG. 8. Isentropic external compression inlets.

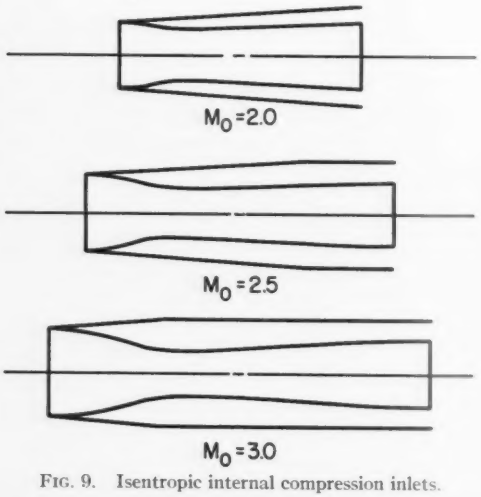


FIG. 9. Isentropic internal compression inlets.

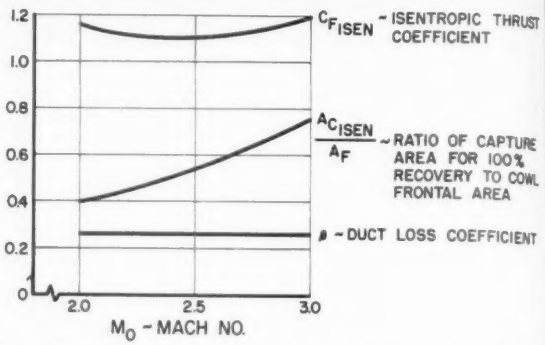

$C_{F_{ISEN}}$ ~ ISENTROPIC THRUST COEFFICIENT
$\frac{A_{C_{ISEN}}}{A_F}$ ~ RATIO OF CAPTURE AREA FOR 100% RECOVERY TO COWL FRONTAL AREA
β ~ DUCT LOSS COEFFICIENT
M_0 ~ MACH NO.

FIG. 10. Typical turbojet engine airflow and thrust characteristics.

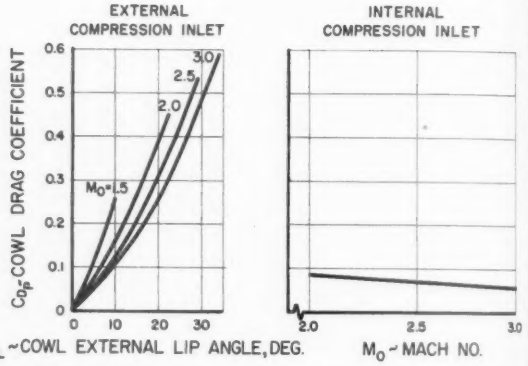

EXTERNAL COMPRESSION INLET
INTERNAL COMPRESSION INLET
C_{D_p} ~ COWL DRAG COEFFICIENT
M_0 = 1.5
θ_L ~ COWL EXTERNAL LIP ANGLE, DEG.
M_0 ~ MACH NO.

FIG. 11. Comparison of cowl drags of isentropic internal and external compression inlets.

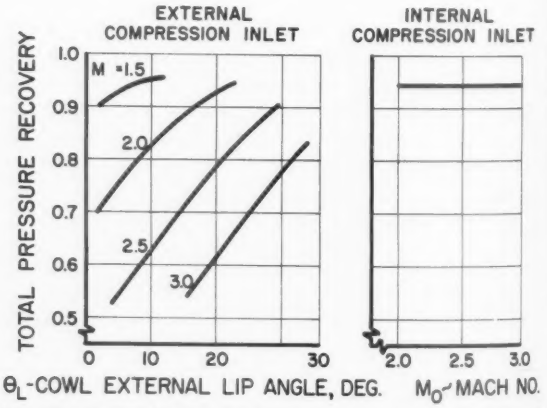


FIG. 12. Comparison of total pressure recoveries of isentropic internal and external compression inlets.

Whether one considers a multishock type or an isentropic inlet, it is apparent that, with increasing external compression, there results an increasing amount of cowl pressure drag due to the steeper cowl angle. Thus for Mach 2 the cowl angle for an optimum recovery two-shock inlet is 13°, while, for an isentropic inlet, the cowl angle is 21°. One would suspect that a balance of thrust and drag forces might indicate an optimum amount of compression beyond which a net loss would be sustained.

Internal Compression Inlets

Another approach to this problem would be to eliminate cowl drag entirely by going to an internal compression type of inlet. As noted earlier, the severe operating problems associated with this type of inlet have discouraged people from using it to date. However, when designing for free-stream Mach Numbers above 2, the indicated drags associated with external compression inlets designed for maximum recovery become so great that it is obvious that a new attempt at a solution of the internal compression inlet problem must be made. In order to provide the necessary impetus for encouraging work toward a new solution, some indication of the magnitude of the possible gains is required. To our knowledge, this has not been done to date largely because of the difficulty in generalizing an inlet design which would have broad application and because of the absence of an easily applied analytical procedure for calculating cowl drag for a three-dimensional body. A rigorous solution requires use of rotational flow characteristics. Attempts to utilize this approach are presently being made with the aid of digital computers. In the absence of any available solution, a simplified analysis has been made for the purpose of this discussion which seems to establish boundaries around the problem and offers some surprisingly clear guidance for induction system selection. The results of this analysis shall now be discussed.

Comparative Performance Analysis

In this analysis, the performances of optimum external and internal compression inlets were compared for each design flight Mach Number. The bases for optimization are (a) an installation which produces the maximum possible propulsive thrust and (b) an installation which produces the maximum range.

The models used for these calculations were a family of circular nacelles with isentropic external compression, shown in Fig. 8, and with isentropic internal compression, shown in Fig. 9. For this analysis it was assumed that the cowl pressures were those obtained from two-dimensional shock at the physical lip angle followed by isentropic expansion to the cylindrical portion of the cowl. This procedure yields conservative drags. However, the final drag data have been modified by arbitrary correction factors of sufficient magnitude to provide an insight into the effect of unconservative drags. These correction factors were obtained by comparing the two-dimensional drags with available experimental drags. The resulting data then show the full range of cowl drag effect for both two-dimensional and three-dimensional inlets.

Other criteria used in designing the external compression inlets are as follows:

(1) The cowl shape is a circular arc tangent to the lip at angle θ_L and to the maximum body diameter established by clearances shown.

(2) The subsonic diffuser was a maximum 6° equivalent conical expansion.

(3) The cowl length was determined by either (1) or (2), whichever was the larger.

(4) A fixed loss coefficient of 0.13 per cent of inlet dynamic pressure was used for subsonic diffuser loss.

(5) Inlet recovery was assumed to be equal to isentropic compression to the Mach Number represented by each cowl lip angle followed by a normal shock and then multiplied by the subsonic diffuser recovery.

(6) The physical lip angle for cowl pressures is equal to that assumed for recovery plus 2°.

(7) Critical flow was assumed for all calculations.

Criteria used for designing internal compression inlets are as follows:

(1) The cowl lip angle extended back at 4° to the same maximum diameter used for external compression inlets.

(2) Inlet recovery was assumed equal to isentropic compression to $M = 1.3$ followed by a normal shock and then multiplied by the subsonic diffuser recovery.

(3) A fixed loss coefficient of 0.13 per cent of inlet dynamic pressure was used for subsonic diffuser loss.

(4) Critical flow was assumed for all calculations.

The details of the analytical procedure are given in the Appendix (see p. 72).

A typical turbojet engine with airflow and thrust characteristics (shown in Fig. 10) was assumed, along with the standard type of thrust and fuel flow correction factors for pressure recovery losses. The cowl drags and recoveries obtained for the two families of inlets are shown in Figs. 11 and 12. A comparison of the general levels of cowl drags and recovery for external and internal compression may be noted in these diagrams. Since the recovery and drag are both dependent variables of lip angle, there is an optimum angle which yields either maximum propulsive thrust or maximum range. The curves for external compression are terminated at the cowl lip angle for which the lip shock becomes detached. Higher lip angles will, therefore, cause such large increments in drags as to preclude optimization beyond this point.

The optimization results for thrust are given in Fig. 13 where the ratio of corrected thrust minus cowl drag to isentropic thrust, $(C_F - C_D)/C_{F_{isen}}$, is shown for each Mach Number. In determining these ratios, arbitrary correction factors K, equal to 1.0, 0.7, and 0.4, were applied to the cowl drag coefficient C_{D_p}. It is our opinion from examination of experimental data that $K = 1$ represents the two-dimensional type of inlet while $K = 0.7$ represents the three-dimensional type. The

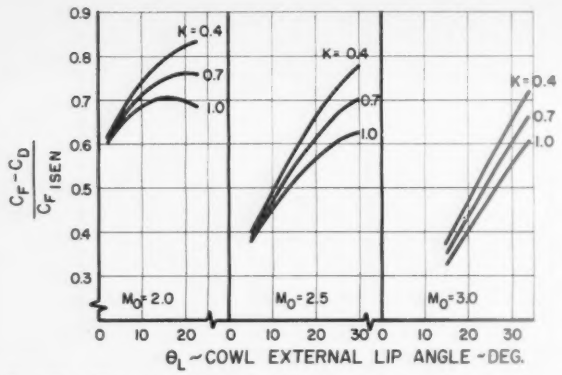


FIG. 13. Thrust optimization of isentropic external compression inlet.

curve for $K = 0.4$ is a value definitely outside any possible errors in the drag assumption. It can be seen that a maximum exists for values of cowl drag correction factor of 0.4 and 0.7 at a Mach Number of 2.0. For all other conditions, no maximums are shown—i.e., the propulsive thrust is still increasing with cowl lip angle up to where the curves are terminated which represents the cowl shock detachment points. For the external compression inlet, there then exists a limit to the amount of compression which can be sustained, and these points represent optimum design conditions. It may be noted that, if the curves for $K = 0.7$ and 1.0, respectively, represent three- and two-dimensional inlets, then they indicate an average 10 per cent advantage for the former.

If the maximum thrust coefficient ratio shown for each Mach Number and K value is now compared to the corresponding value for the internal compression inlet, one obtains the curves shown in Fig. 14. These results indicate that, in the Mach Number range from 2 to 3, the internal contraction inlet has a potential advantage in net propulsive thrust of from 20 to 50 per cent. Cowl drag is obviously extremely significant at these speeds. These values are certainly large enough to warrant serious consideration.

One may now apply the Breguet equation to determine the effect of this analysis on range. If it is postulated that the cowl drag is one of the forces in the net propulsive force balance and is not a portion of airplane drag, then in the equation,

$$R = (V/SFC) \times (L/D) \times \log (W_0/W_f)$$

one may consider the SFC term as an effective SFC where $SFC = W_f/(F - D)$.

The range ratio for internal and external compression inlets is then simply equal to the ratio of effective SFC since all remaining terms are equal. Fig. 15 shows the ratio of effective SFC for isentropic recovery to that for the actual recovery for the external compression inlet and the cowl angle for optimum. As in the case of the thrust optimization, several optimum designs occur at the maximum lip angle which can be employed without cowl shock detachment. If this same limit dictates the optimum design for a given condition, both on the basis of optimum thrust and on the basis of optimum specific fuel consumption, the two designs will, of course, be identical. This occurs, for example, for all values of cowl drag correction factor at Mach 3. Note that in general, however, the two bases of optimization will yield different designs.

An interesting result is that a two-dimensional inlet at Mach 2 achieves minimum specific fuel consumption at 2 deg. cowl lip—i.e., the cowl drag predominates to such an extent that a normal shock inlet is optimum.

Fig. 16 is the final curve in this series, and once again the powerful effect of cowl drag is vividly demonstrated. It indicates gains of from 20 to 30 per cent in range for the internal contraction inlet, over much of the Mach Number range. In making this analysis, it was realized that the assumption of isentropic supersonic compression for both types of inlet tends to favor the internal compression inlet since it inherently has more wetted surface and would therefore be subject to more actual recovery loss due to boundary-layer decrements. A check on this point, however, revealed that it could only affect the results of less than 1 per cent.

CONCLUSIONS

Realistic inlet selection procedures must take into account the entire propulsive force balance. More accurate analysis for determining three-dimensional cowl drags is required. Finally, there are strong indications that for the high Mach Number range the internal contraction inlet offers impressive performance gains over external compression inlets and therefore warrants intensive research to solve the difficult associated operating problems.

APPENDIX

ANALYTICAL COMPARISON OF ISENTROPIC INTERNAL AND EXTERNAL COMPRESSION INLETS

The purpose of this analysis is to compare the performance of external and internal compression inlets, each of which has been optimized for a given design flight Mach Number. Two bases are employed for this

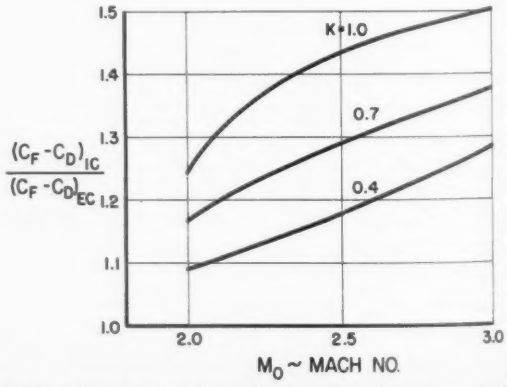


FIG. 14. Thrust comparison of internal and external compression inlet installations.

optimization: (a) an installation which produces the maximum possible propulsive thrust and (b) an installation which produces the maximum range.

(A) *Engine Performance*

For the purposes of this study, the performance of a typical engine at high Mach Number in the tropopause has been synthesized and is presented in Fig. 10. The thrust at 100 per cent total pressure recovery is defined by the coefficient $C_{F_{isen}}$ and the airflow by the ratio $A_{C_{isen}}/A_F$, where $A_{C_{isen}}$ is the area of a free-stream tube whose airflow is equal to the engine airflow requirement.

In the calculation of typical engine performance, an allowance of 12 per cent has been added to the engine diameter to allow for structure and clearance in arriving at the frontal area of the installation (A_F).

Corrections to engine performance caused by inlet duct losses are made as follows:

(1) Thrust: The per cent loss in thrust per per cent loss in total pressure recovery is equal to one plus the duct loss coefficient, (β), of Fig. 10. Thus, the thrust coefficient for a given inlet total pressure recovery is given by

$$C_F = C_{F_{isen}} \{1 - (1 + \beta)\,[1 - (H_3/H_0)]\}$$

(2) Required Capture Area: The engine airflow for high-power, high flight speed conditions (choked jet nozzle) is directly proportional to the compressor inlet total pressure, and the capture airflow is proportional to capture area. Thus, the inlet capture area required to match capture airflow to engine airflow requirements is proportional to total pressure recovery.

$$A_C/A_F = (A_{C_{isen}}/A_F)\,(H_3/H_0)$$

(3) Fuel Flow: At high-power, high-speed conditions, the fuel to air ratio of the engine becomes constant, and the fuel flow is proportional, therefore, to the airflow which is, in turn, proportional to the total pressure recovery. Thus,

$$\frac{W_f}{W_{f_{isen}}} = \frac{H_3}{H_0}$$

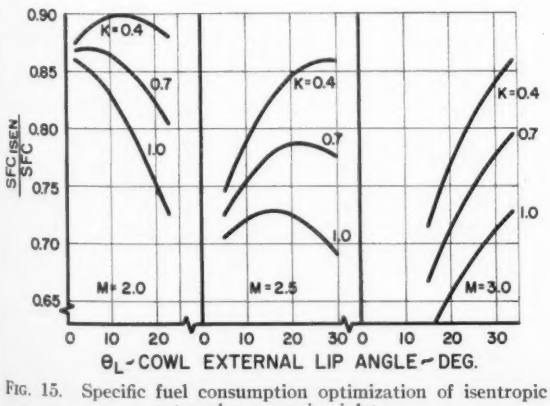


FIG. 15. Specific fuel consumption optimization of isentropic external compression inlet.

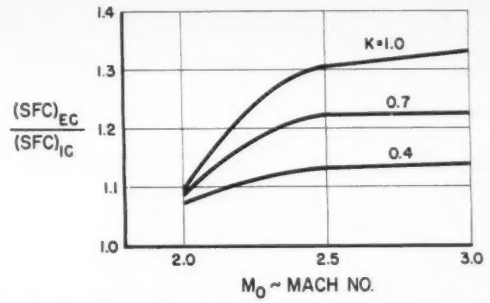


FIG. 16. Specific fuel consumption comparison of internal and external compression inlet installations.

(B) *Total Pressure Recovery*

External Compression Inlet—The total pressure recoveries are computed based on the following assumptions:

(1) Isentropic supersonic compression by means of a curved external compression surface (isentropic spike) followed by a normal shock wave.

(2) Subsonic diffuser total pressure losses equal to 13 per cent of the velocity head just downstream of the normal shock for a 6 deg. equivalent conical diffuser.

$$H_3/H_2 = 1 - 0.13\,(q_2/H_2)$$

For a two-dimensional inlet, the external compression surface profile (isentropic wedge) may be determined from the Prandtl-Meyer solution for isentropic supersonic two-dimensional expansion around a corner since the isentropic compression may be considered simply as flow in the opposite direction. The external compression surface corresponds to a streamline of the Prandtl-Meyer solution, and the cowl lip corresponds to the corner. In order for isentropic external compression to exist, the cowl lip angle must be aligned with the direction in which the flow is turned. Thus, the total pressure recovery may be plotted as a function of cowl lip angle. The results are shown in Fig. 12. Four degrees of thickness at the cowl lip are assumed for structural purposes. This thickness is distributed equally about the direction of the flow—i.e., the external cowl lip angle equals the flow angle plus 2 degrees.

For the three-dimensional inlet, there is no simple analytical solution available for the design of an external compression surface such as exists for the two-dimensional inlet. However, several comparisons of characteristic solutions for axially symmetric inlets with two-dimensional theory show that the relationship between flow angle at the cowl lip and average Mach Number at duct inlet are very nearly the same for both cases. Thus, the total pressure recovery versus cowl lip angle curves of Fig. 12 are assumed to be valid for the axially symmetric case.

Internal Compression Inlet—The total pressure recoveries are computed based on the following assumptions:

(1) Isentropic supersonic compression from the free-stream Mach Number to a Mach Number of 1.3 followed by a normal shock.

(2) Subsonic diffuser total pressure losses equal to 13 per cent of the velocity head just downstream of the normal shock for a 6 deg. equivalent conical diffuser.

$$H_3/H_2 = 1 - 0.13\,(q_2/H_2)$$

This results in a constant value of total pressure recovery of 0.943 as indicated in Fig. 12.

(C) Cowl Drag

External Compression Inlet—For this analysis, cowl drags were predicted from two-dimensional theory and then modified by an arbitrary correction factor K in the light of available experimental data and characteristics solutions. For a two-dimensional cowl, the pressure and Mach Number just downstream of the shock attached to the cowl lip are found by entering the solutions for oblique shock waves with the cowl lip angle and free-stream Mach Number. The pressures at other points downstream are determined from the Prandtl-Meyer solution and the local cowl slope. In order not to produce an abrupt turn internally, a circular arc with the required slope at the cowl lip and tangent to the constant diameter section enclosing the engine is employed. The cowl drag coefficients are obtained by integrating the local pressures with respect to cowl projected area. The two-dimensional results based on cowl projected area as reference area are plotted as a function of cowl lip angle with free-stream Mach Number as a parameter in Fig. 11. Note that, being based on cowl projected area, these results are general.

Internal Compression Inlet—The cowl drag is computed in the same manner as the external compression—i.e., two-dimensional theory results multiplied by a correction factor for axially symmetric flow. Again, 4 degrees of thickness are assumed for structure at the cowl lip. Since the internal surface of the cowl must be aligned with the free-stream direction at the cowl lip in order not to produce an internal shock at the entrance, the cowl lip angle is then 4 degrees for all configurations. Further, since it does not conflict with the internal geometry, the cowl is assumed to be of constant slope of 4 degrees back to the point where the frontal diameter is reached. The two-dimensional drag coefficients based on cowl projected area are plotted versus Mach Number in Fig. 11 for comparison with the values for the external compression inlet of the same Figure.

(D) Engine-Inlet Installation Performance

For the external compression inlet, there is a value of cowl lip angle for each design Mach Number and correction factor K which produces either optimum thrust or range.

For optimization on the basis of maximum propulsive thrust, the parameter $(C_F - C_D)/C_{F_{isen}}$ is employed. This parameter is the ratio of the propulsive thrust of the installation to the thrust of a zero drag installation with 100 per cent total pressure recovery. The total pressure recoveries and cowl drag coefficients (based on cowl projected area) are determined from Figs. 12 and 11, respectively. The thrust coefficient and the ratio of capture area to frontal area are calculated as indicated previously. The cowl drag coefficient based on frontal area is simply the cowl drag coefficient based on cowl projected area multiplied by the area ratio and the correction for axially symmetric flow.

$$C_D = C_{D_P}\,(A_P/A_F)\,K = C_{D_P}\,[1 - (A_C/A_F)]\,K$$

The results are plotted versus cowl lip angle with the cowl drag correction factor as a parameter in Fig. 13. Values of cowl drag correction factor of 0.4, 0.7, and 1.0 are employed in the analysis.

For optimization on the basis of specific fuel consumption or range, the parameter $(SFC)_{isen}/(SFC)$ is employed. This parameter is the ratio of specific fuel consumption of a zero drag installation with 100 per cent total pressure recovery to that of the installation under investigation. Maximization of this parameter will, therefore, minimize the specific fuel consumption of the installation. The specific fuel consumption parameter is easily computed from the results of the thrust optimization study.

$$\frac{(SFC)_{isen}}{(SFC)} = \frac{(W_{f_{isen}}/C_{f_{isen}})}{[W_f/(C_F - C_D)]}$$

$$\frac{W_f}{W_{f_{isen}}} = \frac{H_3}{H_0}$$

Thus,

$$\frac{(SFC)_{isen}}{(SFC)} = \frac{(C_F - C_D)/C_{F_{isen}}}{H_3/H_0}$$

The specific fuel consumption parameter is plotted versus cowl lip angle in Fig. 15 for free-stream Mach Numbers of 2.0, 2.5, and 3.0 in combination with cowl drag correction factors of 0.4, 0.7, and 1.0.

The computational procedure for the internal compression inlet performance is identical to that employed for the external compression inlet. Here, however, since cowl drag and total pressure recovery are independent, only a single design need be investigated at each design condition. Sketches of the designs for Mach Numbers of 2.0, 2.5, and 3.0 are shown in Fig. 9.

A summary of geometries and performances of those inlets is given in Table 1.

TABLE 1

M_0	K	$\frac{A_C}{A_F}$	$\frac{H_3}{H_0}$	$\frac{C_F - C_D}{C_{F_{isen}}}$	$\frac{(SFC)_{isen}}{(SFC)}$
2.0	0.4	0.377	0.943	0.908	0.963
2.0	0.7	0.377	0.943	0.894	0.948
2.0	1.0	0.377	0.943	0.880	0.933
2.5	0.4	0.513	0.943	0.916	0.972
2.5	0.7	0.513	0.943	0.907	0.962
2.5	1.0	0.513	0.943	0.898	0.952
3.0	0.4	0.712	0.943	0.924	0.980
3.0	0.7	0.712	0.943	0.920	0.976
3.0	1.0	0.712	0.943	0.915	0.971

(E) Comparison of Inlets

The two types of inlet are compared on a thrust basis simply by computing the ratio of propulsive thrusts of the internal compression inlet installations to those of corresponding optimum thrust external compression inlet installations at the same free-stream Mach Number and cowl drag correction factor. The results are presented in Fig. 14.

A similar comparison is made on the basis of specific fuel consumption employing the ratio of specific fuel consumption of the optimum specific fuel consumption external compression inlet installations to those of the internal compression inlet installations. (See Fig. 16.)

Techniques and Problems in Testing Structures at Elevated Temperatures

(*Continued from page 60*)

are only capable of producing the heat flux of a vehicle traveling at a speed corresponding to a Mach Number of about 8 or 9 at low altitudes.

Above this range, free flight testing appears to be a solution. There are many unsolved problems associated with this technique, however. Load simulation and instrumentation are two aspects that will require much research and development effort before this system can be used effectively.

Notwithstanding the possibilities of free flight testing, the need for development of laboratory facilities is nonetheless important.

Much work can be accomplished by the methods previously outlined. The principal drawback to most is the enormous power requirements. This barrier is mainly a lack of facilities. For example, a rocket-powered wind tunnel for testing structural elements of reasonable size at elevated temperatures would fill a pressing need.

In the past, structural knowledge and design ability have been capable of supplying almost any aerodynamic shape necessary for flight. This is no longer true, and aerodynamic capabilities are so rapidly outstripping the structural designer's "know-how" that, unless more emphasis is placed on structural research and development, the implementing of many aerodynamic advancements will be slowed.

REFERENCES

[1] Battelle Memorial Institute, *Eleventh Bi-monthly Progress Report on Short Time Creep Properties of Structural Aircraft Sheet Metals*, to WADC, June 15, 1954.

[2] Dotson, Clifford L., and Kattus, J. Robert, *Tensile Properties of Aircraft Structural Metals at Various Rates of Loading After Rapid Heating*, WADC TR 55-199, Part I, May, 1955.

PROCEEDINGS OF THE

FIFTH INTERNATIONAL AERONAUTICAL CONFERENCE

This 560-page permanent bound volume contains the complete papers and technical discussions presented during the Joint IAS-RAeS Conference held in Los Angeles, June, 1955.

Price: $15 (IAS members), $20 (nonmembers)

Publications Department
Institute of the Aeronautical Sciences, Inc.
2 East 64th Street, New York 21, N.Y.

Development of flight-research devices which can be applied to training, systems-development, and instrument-flight problems.

Flight Application of Target-Simulator Principles*

William M. Kauffman†

Introduction

The Ames Aeronautical Laboratory of the NACA has conducted extensive research on the various factors which influence a pilot's ability to track a target with fighter-type airplanes. The effects of changes in airplane stability and control characteristics have been of particular interest. In general, conventional test techniques have been used; simulated attacks have been made against target airplanes, and tracking errors have been evaluated from motion pictures of the target. Unfortunately, this conventional procedure is tedious and expensive. It appeared that such tracking research could be done more quickly and efficiently if the target airplane could be replaced by a simulated target projected on the windscreen. The trouble and expense of a target airplane would thus be avoided, selected attack situations and target maneuvers could be repeated quickly and accurately, and tracking errors could be recorded in continuous time-history form suitable for rapid analysis.

With this in mind, a prototype optical target simulator was constructed and evaluated in flight at Ames. The initial promising experience with this equipment led to application of its principles to other flight-research devices and problems. The additional related equipment which has been developed includes first, a target simulator for use in tracking research involving a scope-presentation fire-control system; next, an airborne drone aircraft simulator for use in studies of simple remote-control systems; and last, a windscreen-instrument display for the pilot's use in performing prescribed maneuvers. It appears that certain features of this research equipment could be applied to a wide variety of problems in the fields of training, systems development, and instrument flight. Accordingly, the present paper will be devoted to a brief description of these four devices—i.e., the prototype and three additional devices—and their flight performance.

Presented at the Advanced Techniques Session, National Summer Meeting, IAS, Los Angeles, June 18–21, 1956.

* This work was performed when the author was an Aeronautical Research Scientist at Ames Aeronautical Laboratory, NACA.

† Electronics and Guidance Division, Aerojet-General Corporation.

Optical Target Simulator

Ordinarily, the pilot's task in tracking with an optical gun sight is to superimpose a gun-sight reticle on the target airplane, both of which are readily visible against the background. With the optical target simulator the tracking task is kept much the same, but in this case the target airplane is replaced by a dot projected on the windscreen. As indicated in Fig. 1, the pilot now attempts to track the larger moving pip representing the target (the tailpipe, if you wish) with a smaller gun-sight pip which is also projected on the windscreen.

No attempt was made in the target simulator to present target attitude or range information but only the line-of-sight orientation, which is considered more important in tracking research. In this regard, one of the first requirements is that the target dot be space-stabilized against the oscillations of the tracking airplane, a characteristic apparent to a pilot viewing, for example, an actual target airplane against a distant background during straight tail-chase tracking. The manner in which the stabilized-target presentation is produced is indicated by Fig. 2. The pilot is shown viewing a fixed gun-sight pip along the gun line and a target airplane along the line of sight. In simulating this target the primary component is a gyro reference system, one axis of which represents the line of sight to the target. The orientation ϵ of this line-of-sight axis with respect to the gun line is measured by electrical pickoffs. Their signals are sent to an optical projector which was constructed from components of a lead-computing gun sight. Here, follow-up servomotors position a mirror so that the dot representing the target is formed on the windscreen (or, actually, on a combining glass) at the proper angle ϵ. The optical projector also provides the other smaller pip which serves as a fixed gun sight along the gun line. (A

lead-computing disturbed-reticle gun sight could, in principle, also be used in conjunction with the simulated target, although this was not done in the present investigation.)

The equipment discussed up to now provides a simulated target which is stabilized against test-airplane oscillations and which, accordingly, can replace a target airplane for straight tail-chase tracking runs. However, the simulation of maneuvering targets is also of interest. For a given target maneuver and flight condition, the pursuit path of the tracking airplane and, hence, the rotations of the line of sight in space can be predicted with good accuracy. For the target simulator, time histories of the rate of rotation of the line of sight are precomputed for selected target maneuvers, and these data are stored in an electromechanical program unit. When a simulated attack is initiated, this program unit sends electrical signals proportional to line-of-sight rates to the gyro reference system. The reference axis which represents the target line of sight is not only gyro-stabilized against test airplane motions but will precess accurately at rates proportional to the command signals from the program unit. The resulting motions of the line-of-sight reference axis, reproduced by the target dot, are thus the same as those which would occur in tracking a target airplane which performs the same selected maneuver.

This target simulator was installed in a Lockheed F-80 airplane for flight evaluation. Comparative fixed gun-sight tracking runs were made against the simulated target and against the actual target for the same standard maneuver, a constant-acceleration breakaway turn entered abruptly after a period of steady straight flight. The pilots felt that the target simulator provided good qualitative matching of actual tracking problems. Tracking errors against actual and simulated targets were equal in steady straight tail chases and slightly greater against the simulated target in steady turning flight. The most apparent difference was the larger error against the simulated target during abrupt turn entries. This difference arose from the lack of wings on the simulated target which ordinarily provide a good warning of the turn maneuvers and was aggravated by the unusually abrupt turn entry which was assumed for the simulated-target case. Thus, addition of target bank angle to the simulator display might be desirable, depending on the particular application of interest.

Oscilloscope-Presentation Target Simulator

The initial promising experience with the optical gun-sight target simulator led to the development of another for use with the E-4 scope-presentation fire-control system installed in an F-86D airplane. This system includes a tracking radar for obtaining target kinematic data and an oscilloscope for displaying computed steering errors to the pilot for corrective action. As shown in Fig. 3, steering errors are indicated by means of a reference circle, whose center is fixed, and a moving steering dot. Vertical and horizontal dot motions correspond to elevation and deflection interceptor flight-path errors, respectively. The pilot's tracking task obviously is to minimize the deviations of the steering dot from the center of the reference circle. This reference circle collapses to a short straight line in the last few seconds. Also shown are a larger circle which shrinks during the attack to indicate the time remaining and an artificial-horizon line which reflects interceptor attitude. All of the information required by a pilot in making a final attack run against an actual target airplane thus is displayed through the oscilloscope. In one sense, the task of replacing the actual target airplane with a simulated target is then simpler than in the earlier case of optical-gun-sight attacks; it is not necessary to provide a separate visual representation of a target but only to duplicate the information normally sent to the oscilloscope for display.

The method used to produce the simulated target is indicated in Fig. 4. In a normal Hughes E-4 attack against an actual target, a radar receiver detects the target position. Radar tracking-error signals are sent as commands to the antenna tracking loop, and various radar data are also sent to an attack computer. The computer processes these and other data and provides the steering signals which are displayed on the oscilloscope for the pilot. For the target simulator, the target range and line-of-sight information normally supplied by the radar receiver are replaced by signals from a program unit in the same manner as in the optical target simulator. These programed data are precomputed for a selected attack situation and thus approximate the data which would be received in a similar attack against an actual target. In addition, a noise generator is used to simulate the major effects of radar noise from an actual target. All these signals are sent to the radar tracking loop and attack computer for processing and presentation in the normal manner.

This target simulator was installed in an F-86D airplane and evaluated in flight by several pilots experienced in E-4 attacks against actual targets. It was their opinion that the target simulator gave a good representation of the steering problem encountered in

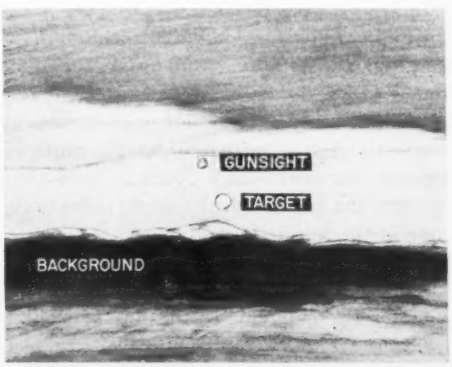


Fig. 1. Windscreen display for optical target simulator.

final attack runs against actual targets, and rough quantitative checks verified that the nature and magnitude of typical steering errors and interceptor maneuvers could be closely duplicated. The programing feature permitted rapid and accurate duplication of any selected initial attack situation, a feature of great value in research. As one interesting sidelight, the fact that noise signals are programed in separately (Fig. 4) makes it possible to study certain effects of radar noise under well-controlled conditions. It appeared that, in addition to the tracking-research application of primary interest in this initial study, the development of similar but more versatile air-borne target simulators may be of interest for other problems, such as pilot training and automatic-interceptor system development.

Air-Borne Drone Simulator

Some time ago, the Laboratory became concerned with the control of drone aircraft by the pilot of a mother airplane. In particular, the evaluation of simplified drone-control systems was of research interest. It was recognized that, although ground simulator studies could furnish valuable preliminary data, the pilot's actual problem of controlling both the mother airplane and the drone simultaneously could be studied more realistically by equipping an airplane with an in-flight drone simulator. Accordingly, the original optical target simulator was converted to an air-borne drone simulator for use in this study.

With a drone aircraft of the type considered here, the pilot would fly the mother airplane in a selected general direction while, at the same time, attempting through radio control to align the drone visually with a selected reference point. This flight-control task as represented by the drone simulator is sketched in Fig. 5, which shows the pilot's view looking through the windscreen of the test airplane. It is seen that the problem appears the same visually as with an actual drone, except that here the drone is represented by a central collimated dot projected on the windscreen (the outer ring of small pips is used for auxiliary test purposes only). This dot responds to disturbances or radio commands in the same manner as the drone aircraft under consideration, and the pilot's control task is identical.

The way in which this simulation is accomplished is shown in Fig. 6. With an actual drone, the pilot views the drone relative to his line of sight to some reference point in the distance. The pilot applies maneuvering commands through a switch or small control stick. A radio link transmits these commands to the drone servosystem, and the resulting control deflections drive the drone in the selected direction.

In the simulator, the pilot's commands are applied to a drone dynamic analog, an analog computer which approximates the behavior of the line of sight to the actual drone. The output quantities are electrical signals proportional to rates of rotation of this line of sight. The analog computer can be adjusted to simulate the response characteristics of a wide class of aircraft. In addition, means are provided for programing various system gains and limits and for applying gravity forces, cross-wind effects, and other simulated disturbances. From here on, the drone simulator is much the same as the optical target simulator. The line-of-sight rate signals are sent as precessing commands to a gyro reference system. However, the reference axis now represents the line of sight to the drone, whose position is reproduced on the windscreen by the optical projector.

As an interesting sidelight, the gyro reference and display system used in the original target simulator had dynamic characteristics which were marginally acceptable for that task. However, satisfactory simulation of the drone aircraft imposed more severe requirements for both better stabilization of the windscreen dot against airplane oscillations and higher speed of response to line-of-sight commands. Fortunately, it proved feasible to retain the major components of the original space reference system by modifications to various system feedback loops which produce the higher dynamic performance required for this new task. Stabilization was improved to the point where pilots could not detect any inadvertent drone dot motions when the mother airplane was subjected to reasonably severe pitch or yaw oscillations (of the order of $\pm 1^\circ$ amplitude at periods of 1 or 2 sec.). The pilots considered the in-flight response of the simulated drone to gravity forces, cross winds, or control commands to be very realistic. It appeared that, through simple adjustment of the drone response analog and modifications to the simulated drone cockpit controls, the equipment would be suitable for pilot familiarization and research studies of a wide class of drone aircraft systems.

Windscreen Instrument Display

By way of introduction, in the diagram of the optical target simulator considered previously (Fig. 2), the windscreen tracking display can be thought of as forming a pitch and yaw flight-attitude instrument. The moving target dot assumes a desired orientation specified by the program unit, while the fixed pip indicates the actual orientation of the gun line. Thus, tracking errors can be interpreted as pitch and yaw attitude errors. Since pilots were able to hold these attitude errors down to a few mils in various simulated target-tracking runs, it appeared that these programing and display principles might be applied fruitfully to certain instrument-flight problems.

To explore this possibility, a windscreen tracking-display instrument was constructed and flight-tested in a fighter-type airplane. The selected flight maneuver was a precision pull-up such as used, for example, with some low-altitude bombing systems. In Fig. 7, the upper curve is a side view of a representative flight path, with altitude plotted as a function of horizontal distance. The flight problem is to repeat this selected

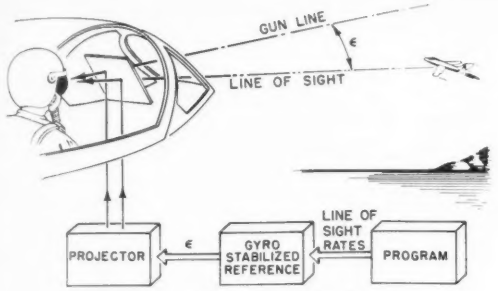


FIG. 2. Optical target simulator.

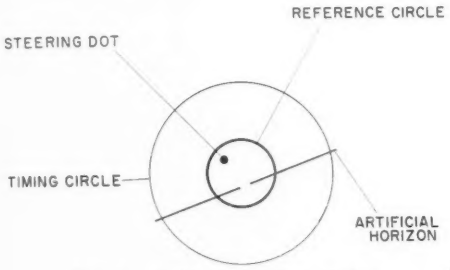


FIG. 3. Oscilloscope attack display.

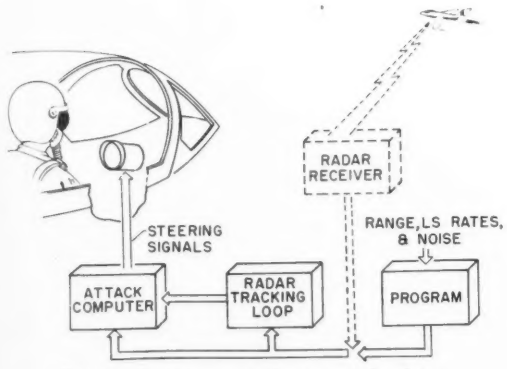


FIG. 4. Scope-presentation target simulator.

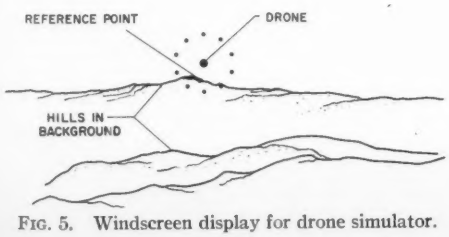


FIG. 5. Windscreen display for drone simulator.

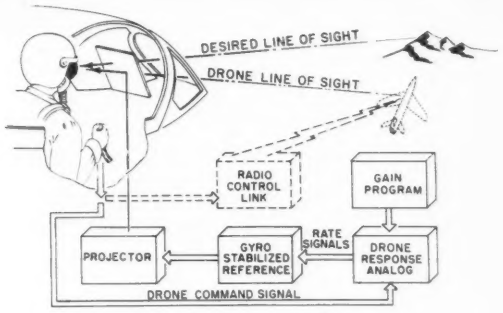


FIG. 6. Drone simulator.

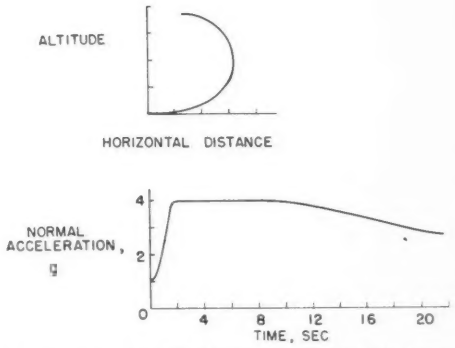


FIG. 7. Typical pull-up for windscreen-display flight instrument.

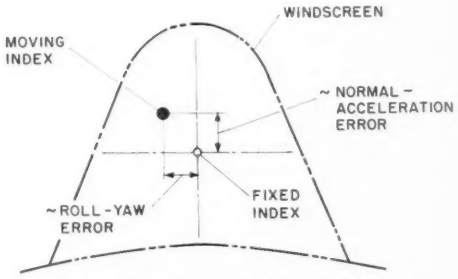


FIG. 8. Instrument display on windscreen.

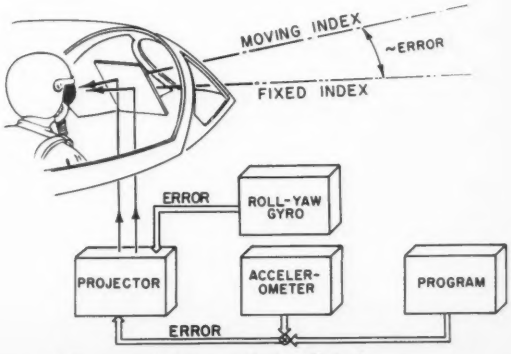


FIG. 9. Windscreen-display flight instrument.

path, essentially a half loop initiated from steady straight flight and maintained in the original vertical plane. The maneuver can be specified readily to the pilot in terms of an initial speed and a time history of the desired normal acceleration, such as the example in Fig. 7. This curve calls for the pilot to pull the airplane up smoothly from 1*g* to 4*g* in about 2 sec. This 4*g* acceleration is then to be held until maximum lift capabilities necessitate a gradual reduction.

The windscreen instrument display developed for this flight problem is illustrated in Fig. 8. As in the optical target simulator display, the smaller dot is a fixed index. The larger dot is now a moving instrument index. Its vertical displacement from a fixed pip is proportional to the difference between the measured and the desired normal acceleration; the horizontal displacement is proportional to airplane roll and yaw deviations from the vertical plane, as sensed by a special gyro. The pilot's task is to track the larger dot with the smaller fixed-sight dot. With perfect tracking the errors are zero, and the desired normal-acceleration pattern will be flown in the original vertical plane.

A simplified block diagram of the equipment is shown in Fig. 9. The desired normal-acceleration pattern is stored in a program unit similar to that used in the target simulator. The electrical output is compared continuously with the output from an accelerometer transducer. The difference, representing the error between desired and measured acceleration, is fed as a command to the servodriven mirror in the optical projector, which displaces the moving index vertically a proportional amount. The roll-yaw gyro here has the spin axis directed along the airplane wing axis to provide a vertical reference plane through the 180° pitch maneuver. Roll and yaw pickoffs furnish a combined signal which is also sent to the optical projector unit to deflect the moving index a proportional amount horizontally. In this research installation, the gains between these dot motions and the measured errors could be adjusted over wide ranges in flight.

Pilots' opinions of this equipment and measured airplane responses were obtained in numerous pull-ups made by several pilots. For comparison, similar maneuvers also were performed using conventional dial-and-pointer panel instruments. With the highly sensitive windscreen display, some tracking difficulty was experienced in rough air and in the maneuver entry. Here the actual normal acceleration tended to lag the specified initial rise—an effect associated with the maneuver abruptness and with delays in pilot and airplane reactions. In addition, random dot motions due to rough air often obscured the maneuver command. With typical windscreen display sensitivities preferred by the pilots, readily detectable tracking errors of one dot diameter (about 2 mils) corresponded to about 0.05*g* acceleration error and about 0.1° yaw error or 0.3° roll error. The tracking performance with this windscreen display was not bad, but it was not appreciably better than in comparable maneuvers made on conventional dial-and-pointer instruments. It is believed that maneuver accuracy and repeatability could have been improved through minor modifications, such as additional filtering, but these were beyond the scope of this exploratory study.

The pilots' comments on this windscreen display were interesting. The opportunity for visual flight monitoring through the windscreen display was not considered a great advantage for the selected test maneuver. The pilots were aware of the outside world flashing by but were too preoccupied with the dot tracking problem to pay much attention. However, they felt that this visual flight-monitoring feature might be very useful in other possible applications, such as landing-approach instrumentation. There were suggestions for minor changes and additions to the windscreen display, such as an artificial horizon. These refinements could be handled more readily if a more versatile optical projector were used—say, a projection-type cathode-ray tube. As to the large tracking dot display itself, the pilots were enthusiastic and considered it a natural, easily interpreted way of combining pitch and yaw information.

Conclusion

The present paper has summarized recent activities at the Ames Aeronautical Laboratory in which principles associated with air-borne target simulators have been used in the development of various research tools. It appears that similar principles and features also could be applied to a wide variety of weapon-systems development, training, and instrument-flight problems.

In considering any of these ideas for other applications, it must be realized that this equipment was designed with limited research objectives in mind and that components from available fire-control systems were utilized where possible. More refined and flexible systems incorporating the same principles undoubtedly can be constructed with current components and techniques.

Necessity of designing an aircraft with wide speed range and large pay load which can fulfill the requirements of battle-area mobility in atomic war.

STOL-VTOL Aircraft in the Air Mobile Army

Lt. Col. Michael J. Strok,* U.S. Army
Office, Chief of Research and Development

Introduction

AVIATION TECHNOLOGY, spurred largely by the needs of the military, has in our lifetime spanned the entire spectrum of human knowledge in the field of aeronautics. The product of this dynamic technology, the aircraft in its many forms, is an established integral part of our national economy and transportation system. In performance vastly superior and in overall cost competitive with most surface-transport means for the efficient, rapid movement of people and things, it is indispensable to our way of life.

So, similarly, the need for the aircraft in the military role is enhanced greatly not only for the basic transportation function it performs so well but even more for the exploitation of the aircraft as a weapons system. In this role, the airplane has become so specialized and so effective a weapon that a whole new concept of national military power—air power—has been created, together with a separate and historically new military service to implement air power.

This is not to say, however, that the basic component in air power—the airplane in its diverse forms and capabilities—was thereby to be selectively applied by a fractional rather than the whole of the national military force. For whatever sophisticated forms and specialized purposes it is designed as a weapons system, the airplane still performs the basic function of mobility to a degree unsurpassed by any other means. An early American aviation prophet, Gen. Billy Mitchell, defined mobility in an airman's terms as "anything that flies." This he defined as air power.

Presented at the Low-Speed Flight Session, National Summer Meeting, IAS, Los Angeles, June 18–21, 1956.

* Army Aircraft Branch, Aircraft Electronics Division.

The statements and opinions in this paper are the author's and do not necessarily represent the official position of the Chief of Research and Development or the Department of the Army.

The Army Mission

The U.S. Army understands the meaning and use of air power in this form and seeks to apply it wherever technically and tactically feasible to expedite and increase the efficiency of the Army in the performance of its mission. Basically, it is to defeat enemy land forces in land combat and gain control of the land, its people, and their war-making potential. Fundamentally, land combat will always consist of fire power and maneuver. In its military meaning, maneuver is battle-area or tactical mobility, using whatever means available. This provides the capability of moving or maneuvering combat units to tactically advantageous positions from which they can, with flexibility and discrimination, apply appropriate fire power tailored to the objective. Mobility is, therefore, an indivisible integral of the military equation of fire power and communication. These three principles form the basis for Army combat doctrine.

Historically, superior mobility has always favored victory in combat over numerically superior forces. The history of nations is in part a history of their success in recognizing, developing, and applying this principle. For several thousand years, man was able to improve his mobility only to the extent of using the elephant and the horse. Only in the past century has man created a technology to serve his mobility needs. In World War I it was the successful but limited use of the internal-combustion engine in the tank, the motor vehicle, and the primitive airplane. World War II saw the use of completely motorized armies and the development of the airplane primarily as a new weapons-system concept while, at the same time, forcing the accelerated development and use of the airplane as a vitally significant means of transport in the strategic mobility role.

In the Korean war, technical development and significant tactical use of a new type of aircraft—the

helicopter—was hastened by the urgency of the need for battlefield mobility in terrain conditions that severely limited operation of conventional airplanes. The helicopter, although limited in desired pay load, range, and speed and lacking round-the-clock operational capability and reliability, pointed up the tremendous potential inherent in simplified, reliable, efficient air vehicles that could operate from rough, unprepared terrain without dependence upon formal runways or prepared airstrips in the combat area.

To prepare for its vital role in the atomic age, the Army must be able to fight the atomic and nonatomic war by the development of streamlined, hard-hitting forces, with great strategic and tactical mobility, coupled with increased fire power from tactical atomic weapons and improved conventional weapons. Future combat will be characterized by a greatly increased requirement for tactical and strategic mobility. Because of the greatly magnified destructiveness of atomic weapons, the need to disperse laterally and in depth for protection and the requirement for rapidly bringing to bear adequate forces at decisive points to exploit the use of atomic weapons have set the pattern for both defense and offense. This vastly increased dispersion results in a much larger battle area that is fluid in nature and therefore largely eliminates the so-called front line. Such a concept requires battle-area mobility that is not limited by conditions of terrain and environment and which, by a high degree of responsiveness to the battle-area commander, can provide rapid movement of combat troops, their equipment, and critical supplies. Only air mobility has that unconditional capability. This has, therefore, created a compelling, urgent need for air vehicles that can live and operate in this environment. They must have the performance capability of an efficient fixed-wing airplane with its pay load, speed, and range, coupled with the short to vertical take-off and landing capability of the helicopter, but without its complexity and cost.

Role of Aircraft in the Army

Since the creation of a separate Air Force by the National Security Act of 1947, the Army, in carrying out its assigned mission, has continued to develop organic aircraft to meet specific requirements in the battle area—namely, observation for surveillance and artillery fire control, movement of small units and critical supplies, and medical evacuation of the wounded from front-line positions. Some 3,800 aircraft, including approximately 1,400 helicopters, are in service. For the most part, they are integrated into combat and combat support units at all levels as special-purpose air vehicles immediately responsive to the unit commander's needs in the performance of a great variety of other tasks such as aerial wire laying, radio relay, battlefield illumination, front-line photography, courier, liaison, etc.

Like the ground vehicles they supplement or replace, Army aircraft live and work in intimate association with the troops they serve. In a combat environment, man and the machines that serve him are forced by the fundamental realities of combat to be simple, reliable, and effective. The soldier's air vehicle must be a simple, unsophisticated machine, easy to operate, easy to maintain, and one that under a wide range of environmental conditions can efficiently and continuously operate from short, unprepared, rough terrain without dependence upon a paved runway or a prepared airstrip. Since ground combat is a round-the-clock reality, the soldier's air vehicle must have a like capability. It must have stability and controllability at low speeds close to the ground and a high degree of maneuverability that is necessitated by such operations. This desired capability should be achieved without major sacrifice of the optimum pay-load and speed potential inherent in the basic design.

Definition of an Army Air Vehicle

Having described the general operational characteristics dictated by the ground combat environment in which these machines must live and operate, we can thus define the Army air vehicle. It is a slow-speed aircraft, which, without the loss of the high speed inherent in the design, has the capability of low, controlled speeds and maneuverability for take-off and landing from rough, unprepared terrain. Simply defined, it is a wide speed-range aircraft with STOL or VTOL performance. This definition then establishes a parametric design envelope within which significant design parameters may be varied to suit the specific mission applications.

Considerations of STOL-VTOL for Mission Application

At the outset, because the Army air vehicle cannot expect the luxury of an air base, the operational requirement suggests a slow-speed STOL (short take-off and landing) as the minimum acceptable for most missions and a VTOL (vertical take-off and landing) design for certain specialized missions. An STOL may be defined as an aircraft having the capability of a 500-ft. take-off and landing distance over a 5-ft. obstacle when operating from unprepared terrain under NACA standard conditions.

In either case, to realize the full potential utility of the STOL or VTOL, it must have a built-in ability to operate from a variety of rough or soft unprepared terrain. This requires that landing-gear design be focused on this specialized operational problem. It suggests a fruitful field for exploration of new design concepts in maximum flotation, high-energy absorption landing gear which must be an integral part of any Army STOL or VTOL aircraft. Although a variety of landing-gear types which might be applicable have been tried on helicopters to date, a completely satisfactory type remains to be proved. The design problem is further complicated by recognition of the operational need to use VTOL aircraft, when terrain permits, as a

STOL type in the overload condition to realize the maximum economic pay-load potential. In some VTOL types this may be as much as a 100 per cent overload.

The choice of STOL or VTOL will be largely determined by the specific mission application. As now foreseen, there are three broad mission areas: battle-area mobility; battle-area observation, short-range reconnaissance, and artillery fire control; and battle-area rescue and evacuation. While certain general operational characteristics, as previously discussed, are common to all three, other operational characteristics are peculiar to each of these broad mission areas. These specific requirements are beyond the scope of this paper since they are stated in detail in various appropriate documents such as military characteristics, general design specifications, etc. The current Army-Navy (Marine Corps) sponsored industry design competition for a medium-performance observation airplane is an example of a specific mission application of a STOL type based on joint Army - Marine Corps military characteristics and general design specifications.

The extent to which new advanced design concepts of VTOL types may be applied for Army use is a matter of considerable study and increasing research and development emphasis. The fundamental work done by Charles Zimmerman and his associates at the NACA Langley Laboratory in the deflected-slipstream and tilting-wing design concepts particularly has stimulated a great deal of research by other research and industry organizations. Believing that full-scale flight experience is the next step in a logical, orderly research and development program, the Army has sponsored, together with the Navy, a program of design and construction of four different flying test beds to exploit the potential of promising VTOL designs of the deflected-slipstream, tilting-wing, and ducted-fan types. Flight test of these dynamically similar test beds is expected to provide valuable data on controllability, stability, vibration, safety, complexity, and other pertinent information which will have a bearing on potential mission application. At this time it is too early to state which of these designs show most potential for specific military uses.

A number of parametric preliminary design studies for short-range utility and small transport aircraft currently in progress with industry are a part of Army research and development in this area to provide by systematic study a family of potential practical designs of STOL and VTOL aircraft. These studies are intended to stimulate industry interest as well as to provide a reasonably realistic basis for the preparation of valid military operational requirements for possible new aircraft types.

While pursuing longer range objectives in the development of new VTOL-STOL aircraft, the Army has been accumulating operational and logistical experience with the helicopter as the first practical vertical-lift aircraft. In over 1 million hours of operation in training, general utility, and combat missions in Korea, the helicopter has proved its value as one of the most significant developments in air mobility and, as such, is now one of the indispensable items of Army equipment. However, perhaps one of its contributions has been in the stimulation of military planners in foreseeing the tremendous potential in vertical-lift aircraft while, at the same time, accelerating the development of new VTOL design concepts on the part of research and industry organizations. These new designs may ultimately supplement or complement the helicopter by the practical development of a capability of greater speed, range, and pay load in which the helicopter is now deficient.

In Army experience to date, the helicopter is essentially a slow-speed, short-range aircraft with a limited pay load, whose greatest value lies in its agility and ability to hover and maneuver at low speeds close to the ground. As a special-purpose vehicle, where hovering is the primary requirement or a large part of the total mission, such as in the heavy lift "flying crane" role, or for medical evacuation and rescue, it remains unexcelled. However, as a troop transporter in an expanded battle area where increased speed and range is the primary need, the better overall performance potential of the STOL or VTOL is most significant.

In this case, range efficiency assumes major importance since the take-off and landing represents a relatively small percentage of the total mission. Improving the range efficiency of the helicopter by attempting to reduce the adverse effects of the rotor blade in forward flight appears, in the foreseeable future, to offer only modest improvement. Known aerodynamic and other limitations such as complexity, unreliability, lack of inherent stability, and high initial and operating costs may seriously compromise continued Army use of the transport helicopter as a significant member of the family of air vehicles.

Continued development effort is under way to increase reliability, pay load, speed, range, simplicity, and maintainability while pressing for reduction in initial and ownership costs. By comparison with fixed-wing aircraft, the helicopter is technically immature. And yet, because of recent advances in technology, it can no longer be considered as the only aircraft type having a vertical-lift capability. This places it in a competitive position functionally with the new VTOL designs. Although the helicopter may, at this point, have a considerable lead in technical and economic supremacy, the basic foundation of some 50 years' fixed-wing experience, when applied to the VTOL designs, may well give them a decisive overall advantage within the next several years.

From the military customer's viewpoint then, assuming for the moment that both the helicopter and the VTOL can perform the vertical-lift function equally well, the advantage appears to be with the machine that has, first, maximum reliability and availability for the efficient performance of its mission and, second, lower operating costs in terms of both dollars and manpower requirements for maintenance, replacement

parts, and fuel. From the logistical point of view, reductions in total support requirements for replacement parts, supplies, tools, and fuel mean a greater percentage of availability of the machine to perform its job and a reduced drain on the supply line, thus making the military organization more combat effective by releasing critical manpower from supply and maintenance duties.

The conclusion that may be drawn here is that our helicopter experience to date should be considered as a realistic guide not only to the design and manufacture of new, advanced helicopters but particularly for practical STOL and VTOL designs for either military or civil use. In many preliminary VTOL designs observed to date, mechanical complexities in the dynamic systems, control systems, and structures comparable to the helicopter are evident, which are primarily due to the need for multiengine reliability and safety.

The comparative operational merits of the STOL, VTOL, and helicopter cannot be discussed with any degree of validity because of lack of full-scale flight experience on the first two types. Where the performance may be very similar, then the selection of type may be determined by such factors as relative ratios of useful to gross weight, relative percentage of time required for hovering, slow speed, or cruise flight, and relative economic factors such as initial and ownership costs. For the VTOL case, if specific weight of installed gas-turbine power plants and specific fuel consumption continues to decrease, this type with its potential of power-controlled approach and zero touchdown speed appears to have an operational advantage over STOL for all-weather operations that may outweigh the economic factor of higher installed power and somewhat less favorable useful to gross weight ratio. For the STOL case, it may be desirable to have VTOL performance in the lightly loaded condition which would make the stability, controllability, and power requirements of the two types comparable.

The design considerations for an Army air vehicle within the previous definition require some clarification. The requirement that it must be reliable, easy to operate, simple, and easy to maintain cannot be met without design compromises which add up to empty weight increases and consequent reduction in useful load. We are prepared to accept this penalty in order to get the optimum balanced military design.

Reliability, which is synonymous with safety insofar as ensuring completion of a mission, is a major consideration. This includes configuration and detail mechanical design of such a nature that, in event of power-plant or component functional or material failure, the aircraft can effect a safe landing. In the case of power plants, proper selection and installation is imperative so that safe, controlled flight can be continued with one or more power plants inoperative without exceeding normal rated power of remaining engines.

Ease of operation or flying qualities implies that the aircraft must be stable and controllable with no excessive specialized, costly, and time-consuming training. Effective overall design, including application of human-engineering techniques, will minimize the number of control loops that the pilot must close in the cockpit for various flight conditions, particularly for all-weather operations, and will increase pilot performance efficiency.

Simplicity and ease of maintenance are requisites that must begin with conscious consideration of this requirement during the early design stages of the development prototype and continue with refinement through all test and preproduction stages. Recognition should be given to design for severe service in the military operational environment rather than the commercial, so that the life of component and individual parts can be increased. The operational environment of dirt, dust, temperature extremes, and corrosion should be considered. All running load-carrying parts and assemblies should, if at all possible, be enclosed in controlled atmospheres. Defining the operational environment and the dynamic and static loading of parts can, by conservative design, increase service life. Another specific area of design for ease of maintenance is by simplification of maintenance procedures. Use of the sealed design and unitized or integral package concept will reduce maintenance at the user or field level. The aircraft should not be used as an expensive repair bench while complicated and delicate dimensional adjustments with special tools and special skills have to be made. The philosophy of "go right or no go" should be applied to design of components, assemblies, and subassemblies for ease of maintenance. Design objective for all major dynamic components should be 1,000 hours between major depot overhauls.

Suggested Research and Development Areas

Advanced, efficient vertical-lift aircraft are not possible without improved lightweight power plants having low specific weights and fuel consumption. The development of the gas turbine, particularly in the turboshaft and turboprop versions for vertical-lift machines, is a milestone of aviation progress. While the Army is carrying on development of the advanced T-53 and T-55 turboshaft and turboprop versions for helicopter and STOL-VTOL application, a higher level of basic research and development effort is required to improve gas-turbine power to weight ratios and fuel specifics and to increase simplicity of control.

Increases in propulsive efficiency over the entire flight-speed range, particularly static efficiency of propellers for some of the VTOL types, are necessary. Ducted propellers or fans as a means of increasing static thrust require more investigation to understand the mechanism of air flow and thrust generation.

The "brute power" approach to VTOL has its practical and economic limits in terms of cost, complexity, and poor fuel specifics. Decrease in pressure and profile drag and increase in propeller or rotor efficiencies will alleviate the requirement for excess power. In this

connection, boundary-layer control, which is considered to be a new parameter in aerodynamics, offers very encouraging and promising results for incorporation in slow-speed aircraft design.

The considerable amount of work to date indicates that a low-energy requirement boundary-layer-control system can provide significant increases in C_L, V_{max}, range, stability, and control, all of which are particularly required to achieve practical slow-speed vertical-lift aircraft.

Improved propulsion systems for VTOL require a fresh design approach to the problem of high static thrust efficiency propellers. Most of the research work in past years has been confined to improving high-speed efficiency up to the high subsonic range at the expense of static thrust efficiency. A balanced STOL-VTOL propeller design requires a large diameter for high static thrust upwards of 8 lbs./hp. without being so large as to compromise seriously cruise speed efficiency by severe underloading. Design C_L must be high for desired static thrust capability. A value of 0.5, when uniformly applied, appears to be an acceptable compromise. Propeller twist for ideal pitch distribution for high static thrust is stated to be 8–10° and for cruise approximately 30°. A compromise toward cruise pitch distribution seems to be favorable and suggests a reliable, lightweight, two-speed gear box which would provide a lower rotational speed for the large diameter propeller in cruise and thus reduce underloading.

Application of boundary-layer control appears to have merit in increasing C_L for operation at higher blade angles for high-speed efficiency or for eliminating stall of inboard blade sections and thus increasing thrust efficiency over a wider operating range. Satisfactory propeller performance and structural characteristics in operation at high angles of attack during transition and descent is still another area in which necessary information for VTOL is very limited.

Another area in which more information is needed is in the development of basic knowledge in the computation and prediction of slow-speed short-landing performance. It appears that—with the introduction of a new family of slow-speed, short to vertical take-off and landing aircraft and the probable necessity of new flight techniques to obtain the maximum performance inherent in these designs during the landing condition particularly—improved, more valid methods of prediction based on experimental verification are required.

The foregoing remarks are quite obviously intended only to highlight a few more obvious areas in which industry can focus development effort. The potential of practical STOL and VTOL aircraft in civil use is sufficiently great that it offers a real development challenge to all in industry who recognize the opportunity.

A Re-Evaluation of Some Air-Frame Thermal Problems

(*Continued from page 66*)

Preprint No. 56-AV-11, presented at the ASME Aviation Conference, Los Angeles, March, 1956.

[10] Anderson, Roger A., *Weight Efficiency Analysis of Thin Wing Construction*, for presentation at a Conference of the Aviation Division of ASME, Los Angeles, March, 1956.

[11] White, D. W., Jr., and Burke, J. E., *The Metal Beryllium*, American Society for Metals, Cleveland, 1955.

[12] Budiansky, Bernard, and Mayers, J., *Influence of Aerodynamic Heating on the Effective Torsional Stiffness of Thin Wings*, Institute of Aeronautical Sciences Preprint No. 579, presented at 24th Annual Meeting, January, 1956.

[13] Goldberg, Martin A., *Investigation of the Temperature Distribution and Thermal Stresses in a Hypersonic Wing Structure*, Institute of the Aeronautical Sciences Preprint No. 577, presented at 24th Annual Meeting, January, 1956.

[14] Mandel, Mervin W., *Comparative Tests of the Strength and Tightness of Commercial Flush Rivets of One Type and NACA Flush Rivets in Machine-Countersunk and Counterpunched Joints*, NACA WR No. L-297, originally issued as RB No. 4B18, May, 1943.

[15] Freudenthal, Alfred M., *On Inelastic Thermal Stresses in Flight Structures*, Institute of Aeronautical Sciences Preprint No. 429, for presentation at 22nd Annual Meeting, January, 1954.

[16] Parkes, E. W., *Wings Under Thermal Stress*, Aircraft Engineering, December, 1954.

[17] Mar, James W., and Schmit, Lucien A., *Some Structural Penalties Associated with Thermal Flight*, Preprint No. 56-AV-9, presented at the ASME Aviation Conference, Los Angeles, March, 1956.

A lively account of the problems associated with the Air Force conversion to combat jet bombers.

Operational Aspects of the SAC Transition to Jets

Col. Richard E. Evans,* USAF
Headquarters Strategic Air Command

LAST YEAR the last Strategic Air Command B-50 Medium Bomber Wing converted to B-47 jet bombers. This year will see the deactivation of the first B-36 Heavy Bomber Wing and the activation of the first two B-52 Wings. Next year, the KC-135 jet tanker will start to replace the KC-97.

The Strategic Air Command has matured from prop-driven adolescence to jet maturity. There have been growing pains, but the rewards and pleasures associated with maturity are usually worth the effort, and such has been our experience.

In November, 1951, Major Gen. Frank Armstrong and the men of the 306th Bomb Wing, stationed at MacDill AFB near Tampa, Fla., were out on the ramp in force, awaiting the arrival of the world's first combat jet bomber. The Wing Commander, Col. Michael McCoy, was delivering No. 1. It was a historic occasion. Probably Napoleon, returning to Paris, felt no greater elation than did Mike. It would have been a great day—except for Growing Pain No. 1.

We had spent millions of dollars and millions of manhours preparing for this moment. A new 10,000-ft. runway had been laid; special new ground power units to start the jet engines had been designed, built, and delivered; new UHF radio equipment had been installed in the tower; and a multimillion-barrel JP-3 tank farm had been built and jet fuel had been moved across the Gulf of Mexico. Jet-engine mechanics had received special training at Scott AFB, Ill., and at the Boeing factory at Wichita, Kan.; veteran B-29 navigators had received high-speed navigation training at Mather AFB, Calif.; and battle-seasoned, 32-year-old pilots had each received $85,000 worth of radar, navigation, and bombing cross-training and a preliminary jet check-out in the T-33. The great effort was justified because one of the new jet bombers would carry to an enemy of the United States in a matter of hours as many megatons of destructive power as all of the American and British bombers in World War II carried to Germany, Italy, and Japan in a 4-year campaign.

We had waited long for this great moment, secure in the belief that everything possible had been done to ensure the success of the 306th Bomb Wing's first jet mission. As Mike approached the runway, six jet engines left characteristic black trails to mark his path. The bicycle landing gear touched down smoothly, and many saw the drag chute for the first time as it deployed and quickly caught the air.

And then it happened! An alert fire chief had seen the "smoke" trailing the bomber, and where there's smoke, there's fire, of course. He raced out in front of a startled Wing Commander and signaled him to stop. In a flash, a fire truck was on each wing spewing Foamite into six brand new J-47 engines.

It was a saddened, red faced Irishman who climbed down the entrance ladder of the B-47 and boarded his staff car for the last leg of his journey to MacDill.

When the Foamite was washed away, we started to compare this airplane with its predecessor, the B-29 (Fig. 1). We observed that it was about the same size

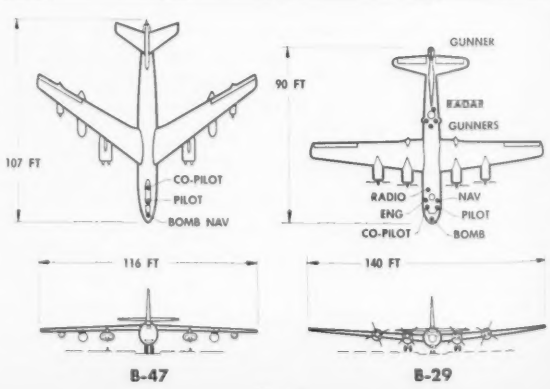


FIG. 1.

Presented at the Operation of Large Turbine-Powered Aircraft Session, National Summer Meeting, IAS, Los Angeles, June 18–21, 1956.

* Deputy Chief, Tactical Requirements Division, Directorate of Operations, Offutt AFB, Neb.

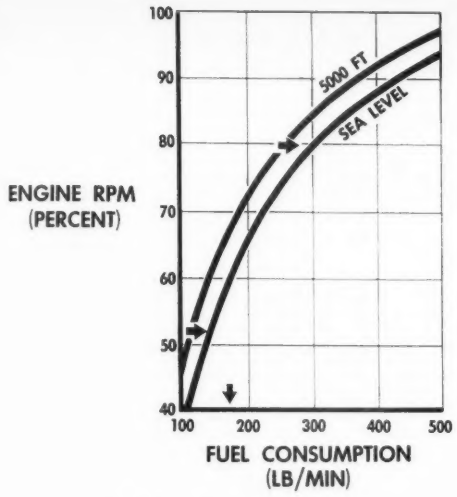


FIG. 2. Ground operation.

but heavier; that its jet engines were out of the wings, suspended on pylons; that its wings were thin, flexible, and sweptback; that the conventional tricycle landing gear was replaced by a bicycle gear; and that, in addition to flaps and ailerons, it had flaperons. And most important, we noted that the navigator, bombardier, and radar and electronic countermeasures operators were now one man; that the pilot and copilot divided the engineer's duties between them; and that the copilot doubled also as gunner, radio operator, and weapons officer. These three men would do the work that eleven men had done in the B-29.

The first lesson we learned was to get off the ground —in a hurry (Fig. 2). Engines Nos. 1 and 6 were held at 52 per cent during ground operation to drive the alternators. Numbers 2, 3, 4, and 5 were varied from 40 per cent, the idle position, to 80 per cent during taxi. The average consumption rate on the ground was 150–200 lbs. of fuel per min. The B-47, at its average weight and flying at its best cruise altitude (Fig. 3), uses fuel at about this same rate. This means, then, that 1 min. on the ground is the rough equivalent of 1 min. of cruise; 1 min. of cruise is 7 miles. Fifteen minutes' delay at the end of the runway means 100 miles less range.

Conventional equipment had not placed such high premium on ground operation. We found it necessary to secure the Air Traffic Control Clearance, including climb-out instructions, before starting the engines. The introduction of surveillance radar during this period greatly facilitated the clearance problem at bases where it was installed.

The B-47 weighs about 85,000 lbs. It can more than double this weight with fuel and pay load, going as high as 220,000 lbs. The wing tanks each carry about 11,000 lbs. of fuel. The balance of the load is distributed, longitudinally, in the fuselage. Great care must be exercised in *first*, limiting and distributing the load for take-off and *second*, distributing the load in flight to keep the c.g. within limits while dropping bombs and while using and replenishing fuel.

The six J-47 engines furnish 36,000 lbs. of thrust at sea level. Water-alcohol can be used to augment this thrust by 17 per cent, the equivalent of a seventh engine. Thirty-three solid fuel rockets provide the power of five or more engines, bringing the total available thrust for take-off up to 75,000 lbs. With this power we lifted a 160,000-lb. B-47 off the runway at MacDill on a hot day in 3,300 ft. With water only, an airplane of the same weight required 6,000 ft. Another, without water or ATO, used 8,500 ft. ATO was rarely employed—it was and is considered an expensive emergency measure. Water was avoided for routine operation in that frequent use resulted in some additional sheet-metal work along the trailing edge and in the flap area.

Runway temperature and field elevation as factors affecting the take-off roll assumed greater significance when we converted to jets. Even with 10,000-ft. runways, it was necessary—in Florida and Arizona, for example—to restrict the fuel load in order to get off with safety. It can be seen (Fig. 4) that a 170,000-lb. airplane, taking off 2,000 ft. above sea level, at 40°F., needs 7,600 ft.; that increasing the temperature to 80°F. increases the take-off run to 10,000 ft.; and that an increase in elevation of 1,000 ft. increases the take-off distance by another 1,000 ft. If the engine exhaust gas temperatures are low, if there is a tail wind, an uphill grade, large amounts of water on the runway, an engine failure, or a miscalculation, the airplane will not get off.

To provide a margin for error and a reasonable safety factor, the maximum take-off weight is determined by the "critical field length." Critical field length (Fig. 5) is the distance required to accelerate the airplane to a particular speed and then either take off on five engines or stop on the runway. This particular speed is termed the "refusal speed." It is calculated for every B-47 take-off and is called out by the copilot as it occurs during the take-off run.

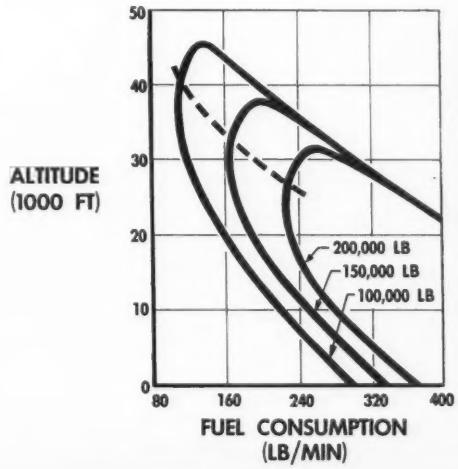


FIG. 3. Level flight.

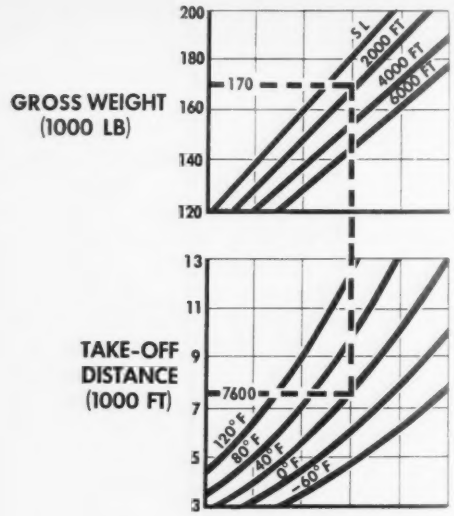


FIG. 4.

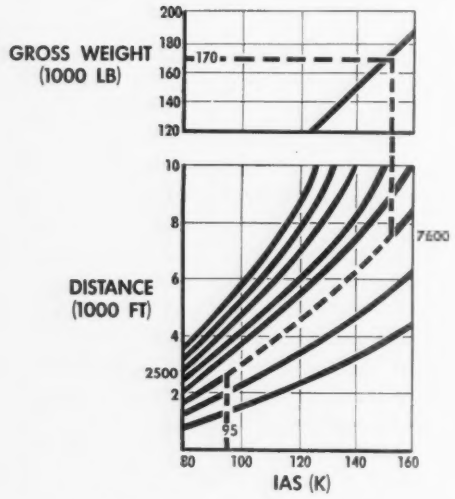


FIG. 6. Line speed check.

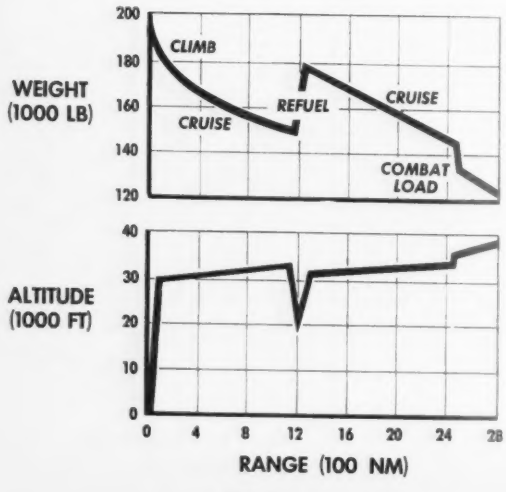


FIG. 8.

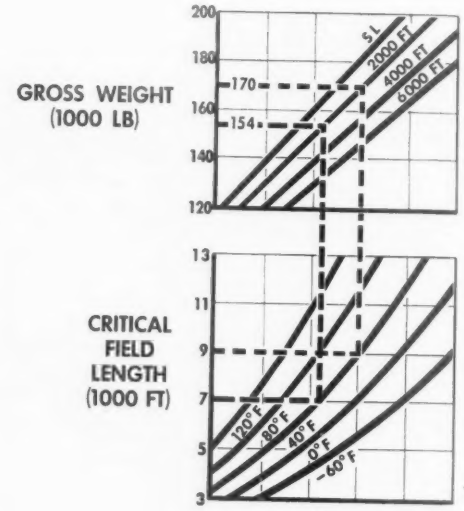


FIG. 5.

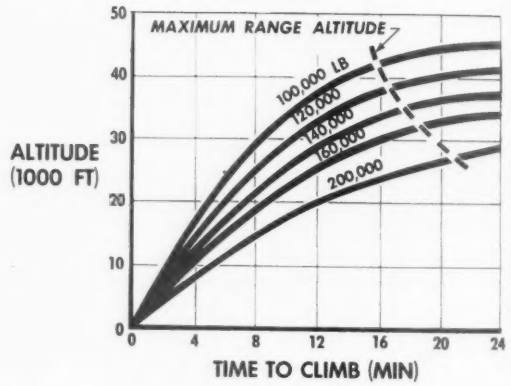


FIG. 7.

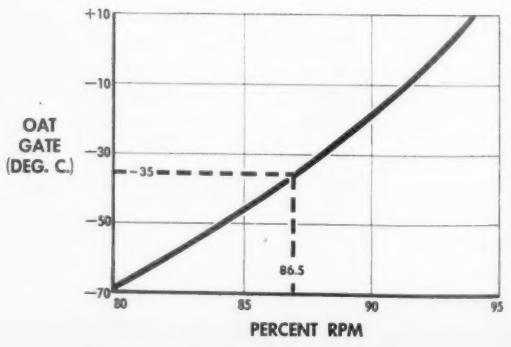


FIG. 9. Optimum r.p.m. for 0.74 Mach.

The 170,000-lb. B-47, taking off at 2,000 ft. above sea level, at 40°F., has a critical field length of 9,000 ft. If the available runway is only 7,000 ft., the airplane is loaded to 154,000 lbs.

The critical field length makes no allowance for chute failure, brake failure, blown tires, unusual runway surface conditions, or pilot indecision at the critical refusal speed. Some method of accurately measuring the acceleration rate early in the run is required to assure a safe abort, as well as a safe take-off.

With this in mind, we marked our runways at 2,500 ft. (Fig. 6) and calculated the speed required at this point. This "line speed" check gave an early indication of the actual rate of acceleration.

Recalling the 170,000-lb. B-47 requiring a 7,600-ft. runway, we find that it should be doing 95 knots at the 2,500-ft. mark. At this point, the aircraft is accelerating at the rate of 6 knots per 1,000 ft. The refusal speed in this case is 116 knots. At refusal speed, the acceleration rate is 12 knots per 1,000 ft., placing a greater premium on time for decision. At "refusal," the aircraft is traveling about 200 ft. per sec. Allowing 3 sec. for pilot reaction and 3 sec. for reducing power, deploying the drag chute, and applying the brakes, it can be seen that the airplane is about 5,000 ft. down the runway, doing about 130 knots, when it starts to decelerate.

Three conclusions can be drawn:

(1) There is a requirement in modern jet aircraft for an "accelerometer" which will total all the variables, including the negative effect of a faulty water injection system or dragging brakes, and give the pilot an early "go-no-go" presentation. (The NACA has developed such a device and is currently testing it on a SAC B-47.)

(2) Ample concrete is the easy solution.

(3) Some form of arresting gear at the end of the runway is desirable. One "save" would pay the entire installation cost of such a device, would buy a lot of concrete.

Flying out of the Marianas in B-29's, we found that significant fuel savings resulted from making the trip to the target essentially on the deck, delaying the climb as long as possible. With the cruise fuel burned out, less fuel was required to lift the lighter airplane to target altitude. This saving resulted in further savings due to the lighter load on the cruise-out.

On the other hand, the cost in climbing a jet engine to altitude immediately is more than repaid by the greatly improved consumption rates at the higher altitudes (Fig. 3). One thousand pounds of fuel will move a B-47 on the deck 18 miles at 425 knots. The same fuel will move a B-47, operating at its best cruise altitude, 58 miles, or three times as far, at the same speed. Power from reciprocating engines is reduced as much as one third after take-off. Jet engines, on the other hand, are maintained at 96–100 per cent of power during the entire climb.

The lightweight B-47 (Fig. 7) starts its climb at 4,000 ft. per min. and averages 2,500 ft. per min. to its cruise altitude. The heavyweight airplane starts out at 2,000 ft. per min. and averages 1,300 ft. per min. With pressurized cockpits, there is little sensation associated with the jet climb-out. The improved rate of climb is dramatic and is fully appreciated only when the airplane bursts through an overcast into the sunlight. This sensation is definitely pleasant.

High air speeds do not encourage ice accretion in flight. Ice is removed as it forms—by dynamic pressures and accelerated sublimation. High rates of climb limit exposure to icing conditions. Ice has not been found to be operationally significant during the jet climb.

Maximum range is obtained in a jet by climbing immediately at full power to an altitude calculated to be optimum for the weight of the airplane (Fig. 8), then flying a constant Mach. As the weight is decreased by fuel consumption and release of the combat load, the airplane is permitted to climb and seek a higher altitude. And after fuel is taken aboard in flight, the process is repeated, starting at a lower altitude corresponding to the heavier gross weight.

To set the airplane up for maximum range cruise (Fig. 9), the outside air temperature gage and the Mach meter are considered primary—with the indicated air-speed or true air-speed indicators, the fuel gages (for calculating weight), and the altimeter as secondary. Upon reaching the calculated optimum altitude, the power setting for the observed OAT is set. The airplane is then permitted to climb or descend to establish the desired Mach. As the OAT changes, power is adjusted and the process continued. With the autopilot altitude control engaged, the airplane will, of course, hold a constant altitude and pick up speed. As the Mach builds up from, say 0.74 to 0.76, the altitude control can be momentarily disengaged to permit the airplane to seek a new level. This "step climb" procedure is a practical answer to the jet cruise climb control problem and has no significant negative effect on range.

A planned step climb, with longer steps, which brackets the optimum climbing flight path, is the answer to the altitude clearance problem. The range loss is not great, can be calculated, and is considered a necessary operational expense.

Except for wind, weather phenomena at jet operating altitudes are not significant. Flight except during refueling is normally above the median-altitude cloud decks; only infrequently is it in high cirrus layers which are thin and dispersed. The moisture content of the upper air is so slight that significant surface ice is never seen. Clear-air turbulence is encountered in the upper air along the shear lines of the jet streams. At cruising speeds, the disturbance causes the aircraft to rock and roll, but there are no sharp bumps such as are encountered at high speeds near the surface or at moderate speeds in thunderstorms.

At 35–40,000 ft., a thunderstorm will occasionally be encountered which appears to reach up to another 10–20,000 ft. These "whoppers" are not seen every day,

but a few form every season in Arizona, New Mexico, Texas, and along the Gulf Coast.

The thin wing of the B-47 can flex 17 ft. at its tip—and *does* in a thunderstorm. This makes for a smoother ride in turbulent conditions with the wings absorbing most of the shock. However, it can be said that few B-47 pilots, after observing their flapping wings in a thunderstorm, share Leonardo da Vinci's thesis that airplanes should fly like birds.

Colonel Mike McCoy was riding in the observer's position in the nose one time, with two student pilots occupying the tandem pilot positions, when a "dark area" was discovered to be a thunderstorm. With no flight instruments before him and being a man with a highly developed inquisitive instinct (in this case he desired to know which way was up!), he growled over the intercom: "One of you guys climb outta there—I'm coming up!" Whereupon, all three pilots met in the passageway.

While the flexible wing absorbs some of the shock, it also warps, acting momentarily as an unscheduled aileron. And as the airplane yaws, the angle of wind over the trailing, sweptback wing is reduced causing loss of lift on this side. At the same time, the other wing is meeting the air stream more nearly at right angles, resulting in greater lift on this side. The overall effect is less stability around the longitudinal axis than is experienced under similar conditions in thicker, straight-winged aircraft.

High-altitude operation makes it easier to detect and by-pass thunderstorms. Forward viewing radar takes the guesswork out of the weather penetration process.

At jet altitudes, 50-knot winds are the order of the day. One hundred knot winds are frequently and routinely encountered; 150-knot winds are occasionally encountered. (They are usually going the wrong way!) We have learned to plot with acceptable accuracy the general pattern of the wind flow at all operational altitudes. However, it is still difficult to predict for a specific time the exact position of the jet streams in space laterally and vertically. Because of the steep gradient of the isotacs (lines of constant wind speed) about the jet stream, again laterally and vertically, the prog must be precise to be useful. For this reason, when operating near a jet stream, it is essential that a running check be made on ground speed and course. Mapping radar is the immediate answer to this problem and is considered an essential item of navigation equipment for modern, long-range jet aircraft.

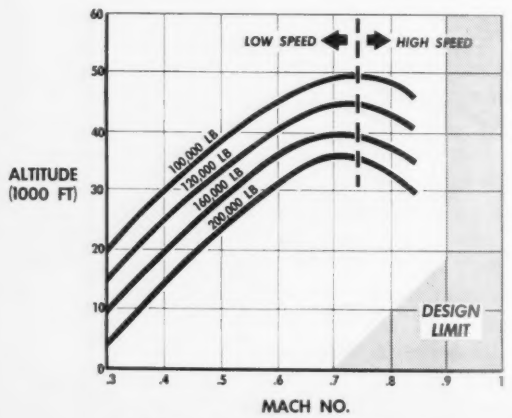


FIG. 10. Aerodynamic ceiling.

It is extremely difficult to get two high-speed aircraft to collide in space, and yet it happens. Even though the probability of mid-air collision is remote, the disastrous result of one such accident is considered to be of such consequence as to cause us to set up in this country an elaborate traffic control system in an effort to reduce this probability to zero. It appears that air traffic over the United States may grow to such proportions as to overload our control system as it is presently conceived and operated. Under such circumstances, the term "military expediency" would, of necessity, be employed more often, and the commercial air transport system would suffer. As mentioned before, jets—commercial or military—cannot afford to delay on the ground, nor can they detour in the sky nor hold for excessive periods over destination.

There is little or no delay in take-off, climb-out, cruise approach, or landing—when it is VFR. A system must be developed which would permit an airplane to clear "VFR" under instrument conditions. We are said to be VFR when we can see with our eyes. We must perfect our "radar eyes" and clear VFR in weather. With air surveillance radar, we put the seeing eye in the tower, limit its range, and give this capability to only one controller. This is like calling in to a traffic cop for a clearance to drive across town instead of turning on the lights and going.

There is a lot of room in the sky. We should use it all, not arbitrarily limit ourselves to certain areas. Our dependence on air routes and 100 per cent ground control during IFR conditions creates much of the congestion we would avoid.

Modern bombers are equipped with nose and tail warning radar. An enemy fighter can thus be detected in time to take defensive action. This system requires that the subject be illuminated by the fighter's radar. The navigator in the B-47, however, can convert his mapping radar into "air surveillance radar" (simply by failing to reduce the size of the altitude hole) and "see" the other aircraft in his formation. The airborne tanker transmits a radar signal which can be seen as a coded indicator on the receiver's scope. Thus the receiver becomes an air-borne "GCI" director.

There are problems, of course, but we are already well out on the learning curve for the development of a device which can see through restrictions to visibility. This development should be pushed.

The B-47 introduced a new expression to bomber pilots—"the coffin corner." It was rumored that, if you ever got into the coffin corner, you would, in the vernacular of the jet jockey, "buy the farm." In the coffin corner, your airplane would stall not only because you were running out of speed but also because you had too much speed! If you pulled back on the

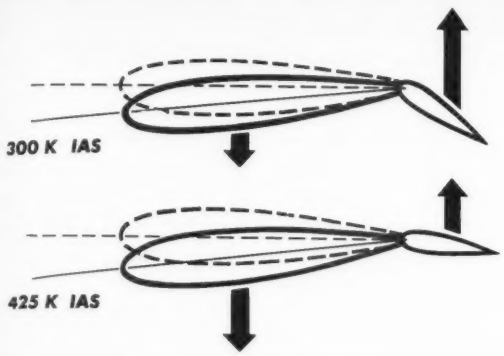


FIG. 11. Aileron ineffectiveness.

stick, you entered a slow-speed stall. If you pushed forward, you would enter high-speed buffet. The coffin corner, we learned, was the altitude at which the air speeds for low-speed stall and compressibility stall, for a given weight, coincide (Fig. 10). For a 200,000-lb. B-47, this occurs at 0.75 Mach at 36,000 ft. A 100,000-lb. B-47 is in the same predicament at 0.75 Mach at 50,000 ft. For the 200,000-lb. airplane, the corner is approximately 9,000 ft. above the best cruise altitude, leaving more than ample margin for a miscalculation in determining weight or altimeter error.

Turbulence further restricts the size of the operating envelope at the higher altitudes. Jet pilots have gotten into difficulty in trying to get above towering cumulus clouds, when actually they should have descended 5,000 ft. below their optimum altitude. Flying below but near the corner, they can be stalled by heavy gusts. Recovery is effected without difficulty, but the airplane quickly slips over into high-speed buffet. With indicated air speed fluctuating wildly because of partial blocking of the pitot tube by moisture and the vibrations of the shock-mounted instrument panel, the pilot is not sure whether he has entered high-speed buffet or a secondary stall. He literally does not know whether he is coming or going.

But of course the coffin corner, or more properly the aerodynamic ceiling, is no more dangerous than an open elevator shaft. When the pilot knows where it is, he can easily avoid it. When he must work near it, he keeps his eyes open.

In the early days, "aileron reversal" was another expression to strike terror in the heart of the neophyte B-47 pilot. It seems that at certain speeds, when the wheel was rolled hard over to one side, the airplane would roll in the opposite direction. This was understandably disturbing.

At high speeds (Fig. 11), the aileron acted on the flexible wing much as a servotab acts on the elevator. The deflected aileron caused the trailing edge of the outboard section of the wing to twist in the opposite direction to the aileron. Thus the wing became a larger control surface than the aileron, neutralizing its effect at certain speeds and "reversing" it at higher speeds.

At one of the fire power demonstrations at Eglin AFB, a B-47 low-level, high-speed pass was included on the program. The B-47 was still new, and most of the viewers were anticipating, with some degree of excitement, their first look at a Stratocruiser. The pilot, anxious to please, had decided to give a convincing demonstration of the speed capability of the new bomber. As he came in at 200 ft., the reviewing stand loomed up ahead of him and a little to his right. A small adjustment in azimuth would position him for a perfect pass. He put in just the right amount of aileron, but nothing happened. He put in more—still no response. Then full right aileron—and then something happened. The airplane rolled *left* and streaked *behind* the reviewing stand!

A large group of Congressmen were in the audience that day. It was reported they were tremendously impressed by the B-47 but that they were greatly concerned about the dimming eyesight of the old men they had heard flew the SAC jet bombers!

The power loading which makes jet flight such a delightful and exhilarating experience can quickly become a force for destruction if the grasp of the reins is relaxed even momentarily. The power required for high-altitude operation (Fig. 12) is literally too much for low- or even medium-altitude operation.

A pilot, flying a 150,000-lb. B-47 carrying "climb power," leveled off momentarily at 10,000 ft. in order to pick his way through broken clouds on a VFR climb-out. His rate of climb had been 2,200 ft. per min., and his indicated air speed 350 knots (420K TAS). In level flight, with no power adjustment, his speed was increasing at the rate of 1 knot per sec. Within 60 sec., he would be entering the critical speed zone. If he eased into a slight (1,000-ft.-per-min.) descent, he would be accelerating at the rate of 1.5 knots per sec. Sixty seconds, at this rate, would bring him well into the danger zone. He turned the airplane over to the copilot at this time and directed his attention to the tuning of his ADF. He stated later that he was distracted for "no more than 30 seconds." When he looked up, the airplane was in a dive of approximately 20° and a bank of 25–30° and had an indicated air speed of 450 knots. He immediately applied full right aileron. The airplane continued to steepen its spiraling

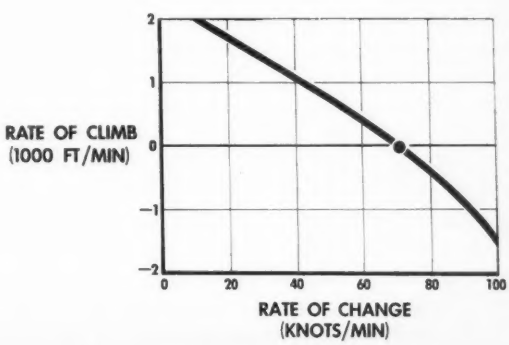


FIG. 12. Acceleration available (96 per cent).

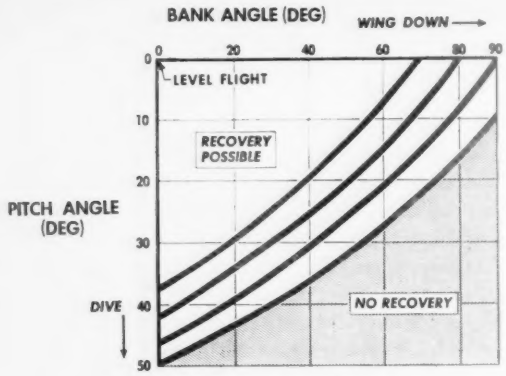


FIG. 13. Critical pitch/bank angles.

dive and in a few seconds struck the ground at a speed of perhaps 600 knots.

The pilot discovered his predicament in time to recover, but he failed to take the proper corrective action (Fig. 13). Had he cut power and applied 125–150 lbs. of back pressure on the stick, he would have effected a 3*g* recovery. With air-speed pitch and bank angle increasing simultaneously, he reached the point of no return in a matter of seconds. Once beyond this point, it is not possible to apply sufficient back pressure on the stick—even with power off—to keep the aircraft from continuing to accelerate. The pilot ejected and confessed he did not fully understand the effects of excessive speed on the aircraft.

Another pilot stalled off the end of the refueling boom into the overcast. He lost control of the airplane and crashed. The copilot, the sole survivor, said he guessed they got into a steep spiral and that, while they were pulling out, the aircraft struck the ground in a level attitude and bounced back into the air. When the final crash did not follow immediately, he assumed they must be on the ground. Noting that there was a large opening where the fuselage had been, he stepped out. Probably recalling that old story about "watch that first step—it's a dilly," he discovered that he was falling in space, pulled his ripcoard, and landed uneventfully. Of course, the aircraft had not hit the ground. It had hit the air at something over 500 knots, but it felt like the ground at this speed.

Probably the most important decision to be made in a jet is *when to let down* because, once the jet leaves the higher altitudes where its engines like to operate, it is committed to land. If it must divert, the decision should be made prior to descent. It cannot fully exploit its range potential and hold in reserve the large amounts of fuel that would permit it to descend, make a pass or two, climb out, and fly to an alternate. (Of course, not all missions require full exploitation of the range potential.) The jet pilot flying above the overcast is completely dependent upon the information he receives from the ground in making his decision. This information must be accurate, complete, and timely. It should even be projected ahead in time to coincide with the aircraft's arrival time.

In the early days, air-borne UHF sets were extremely temperamental, and ground-based sets were few and far between and, we were sure, were turned down so that our infrequent requests would not interfere with regular VHF business. Today, UHF has a high degree of reliability, a UHF ground station is within range or only minutes away anywhere within the ZI, and the CAA stations—the centers in particular—are manned by skilled, solicitous operators.

Time is indeed the essence of the jet pilot's problem, and yet usually the best weather information that can be obtained in flight is an hour old. If he is attempting to formulate his plans 30 min. before arrival, he is forced to *guess* what changes would likely take place in an hour and a half.

We have solved this problem at our jet bases by setting up a UHF pilot-to-forecaster frequency and requiring the forecaster to take *continuous* cognizance of the weather, as opposed to the regular hourly observations, during periods when the ceiling or visibility is marginal.

The Strategic Air Command has a global (northern hemisphere) weather station at Headquarters and sends advisories via land lines and CAA stations to SAC aircraft anywhere in the country. Direct HF transmission has proved unreliable for this purpose. HF-equipped B-47's have had voice contact with Headquarters SAC while flying over Europe—and have been unable to raise Omaha while flying over Kansas City.

The B-47 is not equipped with dive brakes or spoilers, but the landing gear is an extremely effective air brake. There are two basic jet let-downs (Fig. 14)—one with the gear extended, one clean. The gear-down descent is the quickest (6 min. vs. 9) and uses less fuel (530 lbs. vs. 310). However, the clean descent is more economical in both time and fuel when both procedures are started from the same point in space—i.e., 70 miles out. The 30 miles of cruise to the let-down point in the case of the gear-down descent costs another 4 min. and 450 lbs. of fuel. The clean descent is 1 min. quicker and takes 230 lbs. less fuel.

In the idle position, the fuel regulator maintains the power at about 75 per cent at 45,000 ft., 65 per cent at 30,000 ft., 55 per cent at 20,000 ft., and 40 per cent at 15,000 ft. to sea level. This is the reason for the flat descent in the clean configuration at the higher altitudes. The gear-down descent is flattened out somewhat by the 305 knots IAS restriction with the gear extended.

There is little sensation associated with the rates of descent experienced in the clean descent down to 20,000 ft., but the 9,000-ft.-per-min. rate between 20 and 10,000 ft. is something of a thrill, particularly with the high air speed. As a reasonable compromise, we settled on an en route penetration in the clean configuration to 20,000 ft., over the let-down fix. (This is the point where the fuel consumption curve starts to steepen.) The gear was then lowered, and the descent continued

at 4,000 ft. per min., usually in a tear-drop pattern oriented to bring us into the field at the minimum altitude. This procedure required 2 min. more than the clean-all-the-way descent, 1 min. more than the gear-down method. However, it provided for a gear check at an altitude where the fuel consumption was still reasonable, and it was certainly more comfortable.

With tear-drop or 90–270° penetration patterns, using GCA, we have landed full wings of B-47's (45) under instrument conditions at 4-min. intervals. With air surveillance radar and GCA and with straight-in or near straight-in en route penetrations and approaches, we have reduced this separation to 1 min.

LF ADF fixes at jet altitudes are frequently off as much as 15 miles. The old ARN-6 or "radio compass" is unsatisfactory for jet operation. The omnidirectional VOR, on the other hand, is accurate, simple to operate, and reliable. The optimum penetration and approach is from an omnistation located about 100 miles out and generally in line with an ILS. The Cross City Omni and the Tampa International ILS are oriented ideally for a straight-in approach for southbound traffic.

SAC takes credit for discovering and developing GCA. The first GCA approach is believed to have been made at Iwo Jima by a crippled B-29 directed by the radar operator of another B-29 parked on the end of the runway. ILS installations at Air Force bases have had second priority to other projects primarily because our GCA capability was getting the job done. The Air Force recognizes that, for jets and conventional aircraft alike, the ground-radar-monitored ILS is the best system.

There are two basic reasons why the jet landing operation calls for greater precision than does the conventional landing: (1) Jet engines accelerate slowly, and (2) jet aircraft decelerate slowly. The J-47 requires from 12 to 20 sec. to accelerate from 40 (idle r.p.m.) to 100 per cent. Most of this time is required to accelerate from idle to 55 per cent. Obviously, it is desirable to carry 55 per cent of power until the landing is assured. At the same time, however, it is conversely desirable to reduce power to a minimum during the approach to steepen, as much as possible, the characteristic, flat glide angle of the jet. Because the airplane is streamlined and has no windmilling propellers, it does not want to stop flying, and, once on the runway, it does not want to stop rolling. Ten knots excessive speed at flare-out will increase the required runway length by 1,700 ft. On a wet runway, at 3,000 ft. elevation and 80°F., a 120,000-lb. B-47 will stop, using drag chute and brakes, in 5,400 ft. With a GCA touchdown point 2,000 ft. down the runway and 15 knots excess speed on final approach, it will stop just 50 ft. short of the end of a 10,000-ft. strip. If the chute had failed under these circumstances, the aircraft would have required 14,200 ft. on the wet runway, 11,000 ft. on a dry runway.

Approach speeds for conventional heavy bomber and transport-type aircraft may be 30 per cent higher than the stall speed—i.e., 100-knot stall, 130-knot approach speed. To keep from floating right on by the airfield, the jet not equipped with dive brakes, spoilers, or approach chutes must reduce this margin over stall by one half. For example, the 100,000-lb. B-47 stalls at 114 knots; the best approach speed is 128 knots, with 14 knots separation.

Working closer to the stall speed is not dangerous provided two important factors are considered: (1) the increase in stall speed due to bank, and (2) the increase due to *g* forces.

If the 100,000-lb. airplane, approaching the runway at 128 knots, banked in excess of 35°, it would stall. This places a definite restriction on the amount of maneuvering which can be done after breaking a particularly low ceiling, makes a point of killing drift early during GCA and ILS approaches, and emphasizes the need for approach lights out to 3,000 ft.

If 0.25*g* force is placed on the 100,000-lb. B-47 flying at its approach speed, it will stall. The downwind leg is flown at best approach speed plus 30 knots. This excess is systematically bled off during the turn into final. The induced stall is, therefore, not a problem unless there is turbulence or gusting winds or possible downdrafts at the runway threshold. For this reason, great care is exercised to determine if these conditions exist, and, when they do, the final approach speed is adjusted.

There is nothing unconventional about jet traffic patterns. In fact, one pattern is standard at all SAC stations—for jet and conventional traffic alike. Traffic altitude is 1,500 ft. above the terrain, and turn onto base leg is started 45 sec. after passing the end of the runway on the downwind leg, with an adjustment for higher-than-normal wind velocities. Most pilots "eyeball" this point, by starting the turn when the swept-back wing tip passes the end of the runway. Power is adjusted to lose 700 ft. in the 180° turn, rolling out on final at 800 ft.

The bicycle gear was found to facilitate cross-wind landings while the sweptback wing and the approach and brake chutes complicated the cross-wind landing. It was found that the B-47 could be landed without undue risk if the 90° cross-wind component was not in excess of 25 knots. The accepted procedure was to track directly into the runway by holding the wing

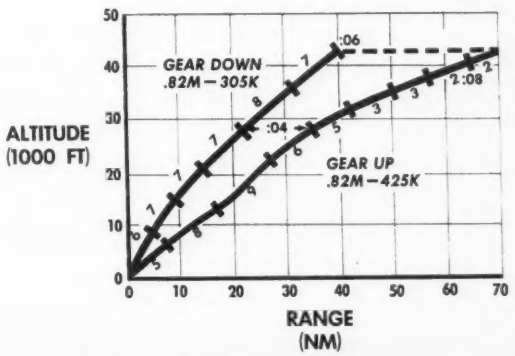


FIG. 14. Penetration times and distances

down on the windward side until the aircraft was actually on the ground. The upwind outrigger gear would touch first. There was no reason, with the bicycle gear, to straighten up before landing, and there was good reason for not yawing excessively. Because of the geometry of the sweptback wing, airflow over the advancing wing during a yawed condition becomes more chordwise, resulting in increased lift for that wing, while flow over the retreating wing becomes more spanwise, thus resulting in a loss of lift and, at extremely low speeds, possibly a stall for that wing.

The permissible 90° cross-wind component is reduced to 20 knots when the approach chute is deployed. Both the approach and the brake chutes tend to hold the rear gear off the ground and "weathercock" the airplane.

If the front grear strikes the ground ahead of the rear gear and if there is excessive speed, the airplane will bound back into the air in a nose-high attitude. If the power has been reduced to the idle position, it is not possible to catch the airplane by sudden use of the throttles. In fact, this procedure will only aggravate the condition. The power will not take effect until the aircraft has flown through a second bounce. If it should happen to be at the peak of the second bounce and if the power comes up unevenly, there may be insufficient aileron to prevent the outboard engine pod on the low-power side from striking the ground.

We flew over a million hours in the B-29 during 1950, 1951, and 1952. We had 189 accidents, resulting in a rate of 17 accidents per 100,000 flying hours. Of these, 68 (36 per cent) were landing accidents.

We flew the B-47 a little less than one-half million hours during 1952, 1953, and 1954. We had 75 accidents, resulting in the same rate as the B-29's—17 accidents per 100,000 hours. Thirty-five (48 per cent) of the B-47 accidents occurred during the landing phase. We have indeed matured, and we have learned many lessons. We have applied these lessons, and the state of the art has advanced.

The larger B-52, weighing over 400,000 lbs., flies higher, faster, and farther than the B-47. With wing spoilers, it lands *more slowly* than the B-47 with better control. The J-57 engine accelerates in half the time required by the J-47.

When thrust reversal is added to the next line of jet aircraft, we will drop the brake chute, and jet flying will have become a relatively simple and safe operation.

But commercial and military jet operators will both have one unsolved problem for a long time to come. Jets are noisy, and Americans prefer their decibels in modest quantity and their cycles-per-second in the ranges of the audio spectrum below 15,000 when possible. Low approaches for landing with the throttles retarded are no problem, but heavyweight take-offs with 100 per cent of power from six and eight jet engines are another matter. If the air lines can solve the noise problem, their transition to jets will be a breeze.

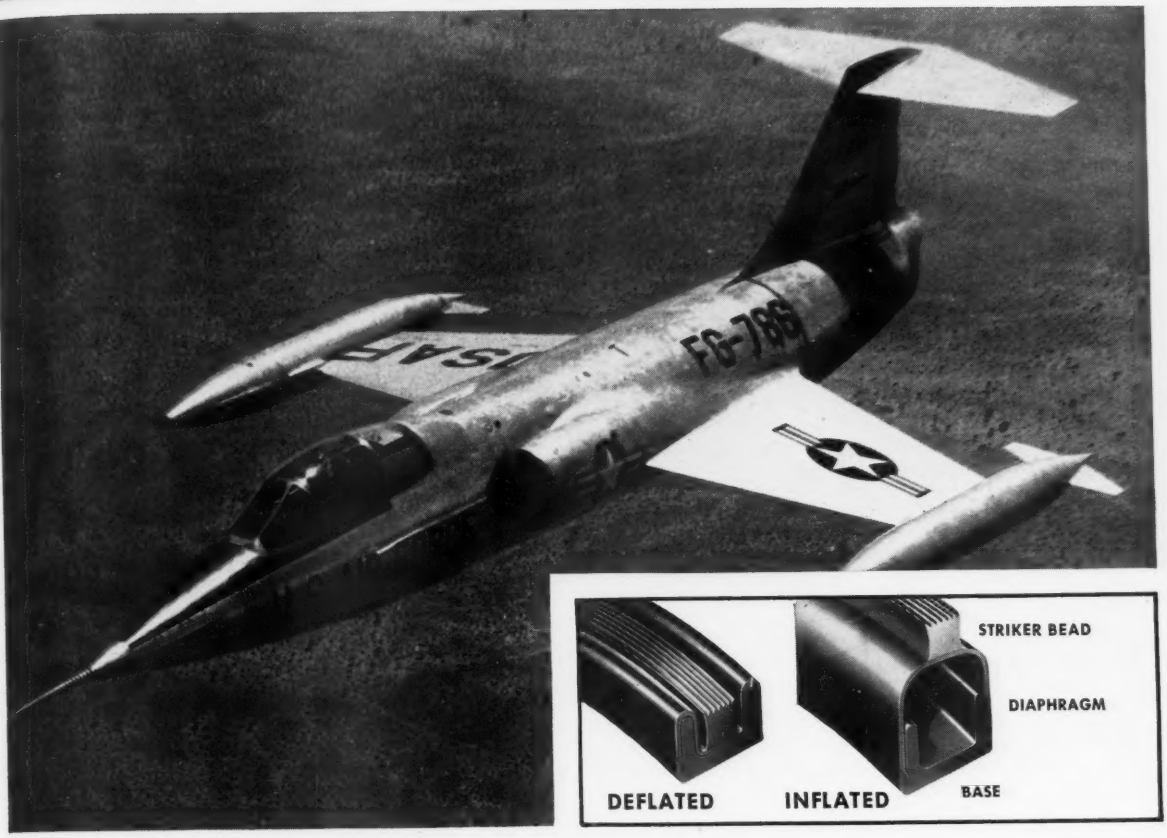
Special IAS Publications

	Member Price	Nonmember Price
Aeronautical Engineering Index – 1954	$ 3.00	$ 5.00*
1953	2.50	4.00*
1952, 1951, 1950, 1949, 1948, 1947 (each)	2.00	3.00*
Proceedings of the Third Turbine-Powered Air Transportation Meeting (1956)	3.50	6.00*
Proceedings of the First and Second Turbine-Powered Air Transportation Meeting (each)	3.50	6.00*
1955 National Telemetering Conference Record	3.50	3.50*
1954 and 1953 National Telemetering Conference Record (each)	2.00	2.00*
Fifth International Aeronautical Conference Proceedings	15.00	20.00*
Second International Aeronautical Conference Proceedings	5.00	5.00*
First and Second Convertible Aircraft Congress Proceedings (each)	3.00	5.00*
Nineteenth Wright Brothers Lecture—Some Structural and Aeroelastic Considerations of High-Speed Flight, R. L. Bisplinghoff (Reprinted from the April, 1956, JOURNAL OF THE AERONAUTICAL SCIENCES)	1.00	1.50
Index to Books on Selected Technical Subjects in the IAS Library (up to 1950), unbound	2.00	2.00*
"Fifty Years of Flight"—A Chronicle of the Aviation Industry in America, 1903–1953, Welman A. Shrader (Published by Eaton Manufacturing Company. Reprinting and Distribution Rights Granted to IAS)	4.50	5.00

*Add $1.00 for orders outside the U.S.A.

These may be obtained by writing to: **Publications Dept., IAS, 2 E. 64th St., New York 21, N.Y.**

B.F.Goodrich



New canopy seal protects F-104 from high altitude blowouts

FLYING on revolutionary knife-sharp wings, the Lockheed F-104 Starfighter is the fastest operational combat plane in the air today. Although actual top speed has not been disclosed, its speed in climb is reported to be equal to its speed in level flight.

To protect the pilots as they blast through the upper atmosphere, all Starfighter production models are equipped with new B. F. Goodrich inflatable canopy seals.

The new seal has a high-lift, quick-action diaphragm of rubber-neoprene, reinforced with nylon fabric. Its precision molded, ribbed striker bead confines cockpit pressurization inside the canopy when the seal is inflated. Upon releasing inflation pressure, the diaphragm has the inherent ability to snap into relaxed position without vacuum assistance. This simplification eliminates parts to save more weight.

Over-all weight is further reduced because the seal's rubber channel base has a compact cross section designed for close tolerances.

Old type extruded seals stretch when inflated, like a toy balloon—with the possibility of blowouts at extremely high altitudes. B. F. Goodrich seals inflate to maximum height without stretching—like a paper bag. This means longer service life and uniform sealing pressure at all points. That's why B. F. Goodrich seals are already being used on more than two dozen makes and models of jet fighters and bombers.

Why not turn your sealing problems over to B. F. Goodrich engineers? They are ready to give you expert help on canopies, doors, bomb bays, capsules, compartments and other specialized seal applications.

B. F. GOODRICH AVIATION PRODUCTS
A Division of The B. F. Goodrich Co., Akron, Ohio

B.F.Goodrich

Tires, wheels, brakes • De-Icers • Inflatable seals • Fuel cells • Avtrim • Heated Rubber • Pressure Sealing Zippers • Rivnuts • Plastilock adhesives • Hose and rubber accessories

IAS News

(*Continued from page 43*)

either extended solder cup contacts or with taper pin contacts.

• **Bell Aircraft Corporation** has announced the addition of a new helicopter to its commercial line—the four-place, single-rotor Model 47J, which will be known as the Ranger. First commercial deliveries are scheduled for early 1957. A demonstrator, with a special paint job and special name, "El Picaflor Plateado" (The Silver Hummingbird) is scheduled to return to the United States this month following a 17,000-mile aerial tour of Central and South America.

• **Bendix Aviation Corporation . . .** Representatives of 20 major world and domestic air lines met at South Bend, Ind., the week of August 27 to discuss aircraft fuel systems as applicable to a commercial aviation. The event was the Fuel Systems Forum, sponsored by Bendix Products Division. . . . The Products Division has named Dale Falkner, Airframe Equipment Sales, coordinator of a Bendix-Government sales group. . . . Ralph A. Lamm has been appointed Director of Engineering, Pacific Division. He is former Head of Special Missile Development at the Bendix Research Laboratories Division. . . . Robert W. Hallam has been appointed to the new post of District Sales Representative in the San Francisco area for the Eclipse-Pioneer Division.

• **Boeing Airplane Company** has been elected to membership in the Radio Technical Commission for Aeronautics. E. N. Snider, Staff Engineer, Electro Dynamics, has been named delegate to the RTCA Assembly.

• **Curtiss-Wright Corporation . . .** Roy T. Hurley, Chairman and President, has had his first meeting with H. E. Churchill, new President of Studebaker-Packard Corporation, following signing of an agreement between the two companies which brought the auto firm $35 million in new financial resources. The two officials have planned a "new and different approach" to auto production and marketing.

• **Douglas Aircraft Company, Inc. . . .** DC-8 electronic equipment may weigh as much as a ton and cost $140,000—more than the entire cost of the prewar DC-3, according to R. H. Jerome, Douglas radio systems engineer. . . . The X-3 "Flying Stiletto," high-performance research airplane built by Douglas for the Air Force and first flown in late 1952, then turned over to NACA, has been retired. Final disposition will be up to the USAF.

• **Eaton Manufacturing Company . . .** Having observed its Silver Anniversary in September, the Dynamatic Division is looking forward "to the development and manufacture of many new products and new versions of present products . . . which should mean ever greater prosperity," according to F. L. Hopf, Division General Manager. The Division has made many contributions to the railroad, aircraft, automotive, textile, and a diversified list of other manufacturing industries.

• **Elastic Stop Nut Corporation of America** has announced a new line of counterbored, self-aligning, hexagon locknuts for fastening applications involving nonparallel surfaces. Type LH2395 fasteners, according to the company, offer significant cost- and weight-savings and reduce production time by eliminating machining, milling, individual selection of tapered shims, or other preparation of the forgings presently used to obtain the required parallel bolting surfaces. Features listed are parts adaptable to either short- or long-thread bolts, reusability, protection against loosening, and performance to AN-N-10 and/or MIL-N-25027 (ASG) specifications for temperatures up to 550° F. It is announced that thread sizes currently designed are 1–32, 1/4–28, and 5/16–24.

• **Fairchild Engine and Airplane Corporation . . .** Some of the closely guarded details of Petrel, an air-to-surface missile produced by the Guided Missiles Division, have been released by the U.S. Navy. It was disclosed for the first time that Petrel consists essentially of an air frame with guidance, stabilization and propulsion units, and a torpedo-type pay load. It is about 24 ft. long, has a wing span of 13 ft., and weighs 3,800 lbs. Its heart is a Fairchild electronic brain, described by the Navy as sophisticated, which thinks for itself and guides the missile to its target at high speed and with "devastating effects."

Roy T. Hurley, Chairman and President, Curtiss-Wright Corporation, is shown at *right* with H. E. Churchill, new President of Studebaker-Packard Corporation.

• **Fairchild Instrument and Camera Corporation** Board of Directors has elected Major Gen. Kenneth P. McNaughton, USAF (Ret.), a Vice-President, Board Chairman Sherman M. Fairchild has announced. The General recently joined the firm as Director of West Coast Operations.

• **Federal Telecommunication Laboratories, Division of International Telephone and Telegraph Corporation . . .** An air line is conducting translantic flight tests of an air-borne radioteleprinter that continually and automatically clatters out the latest weather information from stations in Canada and Scotland. Signals have been received at a distance of 1,300 nautical-miles.

• **The Firestone Tire & Rubber Company** has announced a new nylon tire in all sizes for light aircraft which replaces tires of rayon construction at no increase in price for the same size and ply rating. Two sizes of the new product, 7.00-6 with 4-ply rating and 11.00-12 with 8-ply rating, are available now. Eight additional sizes and styles, to equip every type of light plane, soon will be on the market.

• **The Garrett Corporation . . .** J. C. Garrett, Founder and Chairman of the Board, announces that La Motte Cohu has been elected to the Board of Directors. He replaces John K. Northrop, who has retired. . . . Bryan Sandford Clark, of England, has been named Foreign Representative in charge of the Corporation's widely intensified activities in Europe. . . . Wider expansion of its international market in the aircraft accessory and component field among an increasing variety of European aircraft manufacturers is indicated in a recent report by the AiResearch Divisions in Los Angeles and Phoenix. . . . An electrically heated windshield, equal to those on the latest production aircraft, has been installed by the AiResearch Service Division on a DC-3 converted for the Libbey-Owens-Ford Glass Company. It is of the single-piece type and has its own power system. Another advantage claimed is that its half-inch thickness makes it birdproof.

• **General Dynamics Corporation . . .** An expanded market and route analysis department at Convair Division has been formed. It is expected that the single department will provide a more effective tool to support the sales program for the new Model 880 jet transport. Studies are being made to determine how 880's will fit into air-lines' routes and markets. . . . Four large concrete jet-engine silencers are being built for the F-102A interceptor program at Convair's San Diego facility.

IDEAS...*on making the most of wire cloth!*

• Unless you're in the business up to your ears, you'd hardly be aware of the infinite variations that can be offered today in industrial wire cloth. Not only variations in the wire, metal, weave and mesh, but also in finishes, coatings, roll lengths, widths and packaging. And the *Reynolds Wire Division* of National-Standard has carried this flexibility to a high point in the industry.

So, you can see that it is mighty important for users or fabricators to probe today's possibilities carefully, and to be *sure* they are getting *the* wire cloth that produces best, performs best, minimizes waste, and costs the least for their particular production.

And that is exactly why *Reynolds Wire Division* goes all out in furnishing technical and analytical service—service that benefits customer after customer, small or large. This exceptional service is available coast to coast . . . wherever you are.

Are you open to some ideas on making the most of wire cloth? Do you have any particular production problems in the use of wire cloth? Let's discuss your requirements.

NATIONAL-STANDARD COMPANY • NILES, MICHIGAN
Tire Wire, Stainless, Fabricated Braids and Tape

ATHENIA STEEL DIVISION • CLIFTON, N. J.
Flat, High Carbon, Cold Rolled Spring Steel

REYNOLDS WIRE DIVISION • DIXON, ILLINOIS
Industrial Wire Cloth

NS NATIONAL-STANDARD Company NILES, MICHIGAN

WAGNER LITHO MACHINERY • JERSEY CITY, N. J.
Special Machinery for Metal Decorating

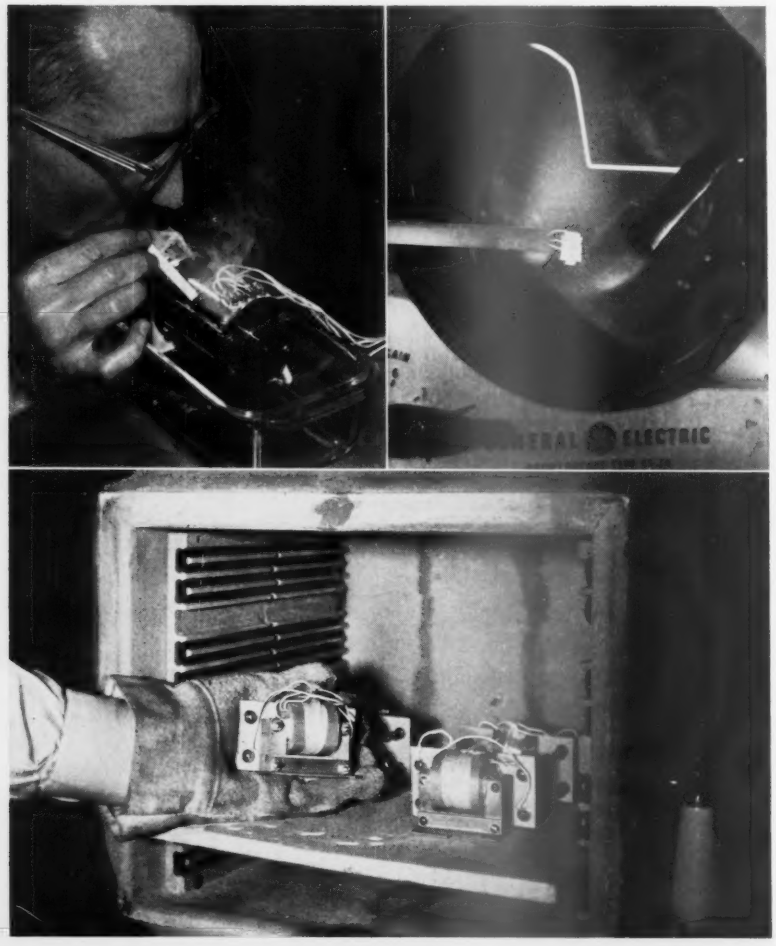
WORCESTER WIRE WORKS DIVISION • WORCESTER, MASS.
Round and Shaped Steel Wire, Small Sizes

The cost will be nearly $1 million. . . . Four Navy jet fighters have been refueled simultaneously in flight off the California coast by a Convair R3Y-2 Tradewind. Time required was less than 5 min.

• **General Electric Company . . .** Models of revolutionary electronic devices and circuits operating literally red hot were displayed by G-E in New York recently to bolster its claim that it had penetrated a critical temperature barrier. The company held that an important plus feature of the model circuits was ability to operate for long periods while exposed to nuclear radiation in an atomic reactor. "Tremendous defense implications" were attributed to the devices by C. G. Suits, G-E Vice-President and Director of Research. Dr. Suits said progress reflected by the demonstrations was the result of "extraordinary teamwork" among the G-E Research Laboratory, nearly a dozen other departments and labs, and various United States defense agencies. Inside glowing electric furnaces and surrounded by blowtorches, the company's new vacuum tubes, capacitors, resistors, transformers, inductors, wires, printed circuit boards—and even an electric motor—were operated in temperatures ranging from 900 to 1,500° F. George L. Haller, AFIAS, called the development "a milestone in the aviation and electronic industries—and in the defense of our nation." Dr. Haller is General Manager of G-E's Defense Electronics Division. Similar importance to the future applications of atomic energy was emphasized by D. Roy Shoults, AFIAS, who is General Manager of the Aircraft Nuclear Propulsion Department. Gaylord W. Newton, AIAS, who is Manager of Application Engineering at the Aircraft Nuclear Propulsion Department, described in some detail the tests in which electronic circuits were operated for over 1,000 hours in the graphite reactor at Oak Ridge National Laboratory.

• **G. M. Giannini & Co.** announces the production of a new addition to their line of extremely accurate Adiabatic Temperature Probes for measurement of air-stream stagnation temperatures in aircraft and missile applications. Designated Model 49127, either of two fast response temperature elements is available to provide a voltage or resistance output proportional to air-stream stagnation temperature. Suitable for telemetering and control or the sensing of flight data for air-borne systems, these precision instruments offer a recovery factor of 0.985—essentially unity—with response time of 0.25 sec. or less and repeatability within 0.5 per cent. Housings are of stainless steel; all exposed surfaces are highly polished to minimize emissivity and reduce aerodynamic friction. The company reports that excellent aerodynamic configuration helps to provide superior performance over the wide velocity range of Mach 0.3 through 2.0 at altitudes as high as 60,000 ft. Further information may be obtained from Scott Malcolm at the company's Pasadena, Calif., headquarters. . . . The company also announces the 86125A Pancake Rectipot, a miniature spring-loaded linear motion precision potentiometer, designed for applications requiring measurement of a short stroke in limited space. Standard stroke ranges from 0.1 to 0.5 in. are offered in resistance ranges of 1,000 and 2,000 ohms with linearity of ±1 per cent and resolution of 0.0012 in.

(Left) A G-E motor, so hot that it will light a cigarette, has operated successfully for 50 hours at temperatures of 500°C. (Right) A new G-E vacuum tube (laboratory model of the 6BY4 microminiature ceramic tube) operates, as indicated by the oscilloscope pattern in background, even when red hot in a gas flame. (Bottom) High-temperature transformers designed and built by G-E are pictured in an electric oven in which they have been operated for long periods in an atmosphere of 500°C.



• **The B. F. Goodrich Company . . .** Three appointments in its Aviation Products Division have been announced by the company. Charles H. Kanavel has been appointed Field Sales Manager. Carroll P. Krupp is Manager of Product Development, and G. G. Zimmerman has been named Manager of Tires, Airlines, and Distributors.

• **Grumman Aircraft Engineering Corporation** has acquired a 50 per cent interest in Dynamic Developments, Inc., a hydrofoil research organization at Islip, L.I. Leon A. Swirbul, Grumman President, said the new association will combine Dynamic Developments' hydrofoil research experience with Gumman developmental and production facilities. William P. Carl is President of the hydrofoil firm, and associated closely with him as a Director is Robert R. Gilruth, TMIAS, Assistant Chief of Research at the NACA Laboratory, Langley Field, Va. Initial joint effort of the two companies involves study on the application of hydrofoils to military craft, flying boats, and amphibious aircraft.

• **Harvey Aluminum Division of Harvey Machine Co., Inc. . . .** An illustrated technical brochure containing full details on the new hollow aluminum bar stock developed by Harvey has been issued by the Torrance, Calif., company. Tolerances, mechanical properties, and applications of the hollow machining stock are discussed. Case studies are presented. A free copy of the 8½ by 11 in. brochure, entitled *Hollow Aluminum Bar Stock*, can be obtained from the Division at 19200 S. Western Ave., Torrance.

• **Walter Kidde & Company, Inc. . . .** The Aviation Division has established a coast-to-coast network of aviation fire-extinguishing system recharge and service stations in the United States and Canada. Twenty-four-hour-a-day service now is available in Atlanta, Ga.; Dallas, Tex.; Denver; Houston, Tex.; Kansas City, Kan.; Miami, Fla.; Mobile, Ala.; San Diego, Calif., Seattle; Van Nuys, Calif.; Belleville, N.J.; and Montreal, Canada. Kidde maintains similar stations overseas. Ad-

Leon A. Swirbul, Grumman President, and W. P. Carl, *left*, President of Dynamic Developments, Inc., register approval after Swirbul signed agreement by which Grumman acquired a 50 per cent interest in the hydrofoil research activity. At *right* is Robert R. Gilruth, TMIAS, a Dynamic Developments Director.

ditional ones will be established as needed. . . . Robert L. Dickson, Vice-President and Controller, has been elected Chairman of the Executive Committee of Controllership Foundation, Inc., research arm of the Controllers Institute of America. He also was renamed a trustee of the research group.

• **Lear, Incorporated,** announces opening of a new research and development building adjoining its other facilities at Santa Monica Municipal Airport. It will house the West Coast Engineering Branch of the Grand Rapids Division, which has recently developed an attitude indicating system to provide improved blind flight capacities for helicopters. Designated Model 4005H, the new VGI (Vertical Gyron Indicator) is completely transistorized for increased reliability and compactness. It has been specified as standard equipment for the Navy HUS-1 (Sikorsky S-58) and HR2S (Sikorsky S-56) helicopters following completion of a flight-testing program initiated by the Bureau of Aeronautics, Airborne Equipment Division, Instruments Branch. . . . Having under construction a 14,000-sq.ft. addition, the Lear-Romec Division reports that its total plant space soon will be 74,000 sq.ft. in Elyria, Ohio. Space has been increased 64 per cent since 1952. The Division employing about 400 persons, recently announced the Lear-Romec Model RG-15150-A Line Transfer Fuel Pump. The pump, designed for extreme temperature ranges, is used in aircraft for transferring fuel from auxiliary tanks to main fuel tank or as a starting and emergency pump. Further data will be supplied by R. S. Atkinson, at Elyria offices. . . . The Aircraft Engineering Division reports that a third Learstar Mark I high-speed business airplane has been ordered by U.S. Steel. Longer range (fuel totaling 1,350 gal. will be carried) will be the only change.

• **Lockheed Aircraft Corporation . . .** Six top-level executive appointments at the Georgia Division have been announced by D. J. Haughton, General Manager and Vice-President of the Company. All were effective October 1 and follow an earlier announcement of Haughton's election as Executive Vice-President in Charge of All Operating Divisions. H. Fletcher Brown, Manufacturing Manager of the Division since 1952, becomes Assistant General Manager succeeding A. Carl Kotchian, who was elected General Manager and a Vice-President of Lockheed succeeding Haughton. Ralph J. Osborn, Assistant Manufacturing Manager, will be the new Manufacturing Manager. R. A. Mackenzie, Production Manager, becomes Assistant Manufacturing Manager. H. Lee Poore, Assistant Production Manager, becomes Production Manager. William B. Rieke, Director of Materiel, will be new Assistant Production Manager. Nicholas Ricciardi, Purchasing Department Manager, is new Director of Materiel. . . . The Missile Systems Division soon is to avail itself of the services of an electronic brain known as the Univac Scientific 1103A. The first of its kind ever built, it is reported the only machine in the world versatile enough to interrupt one complex problem to solve a new, high-priority problem while retaining all work on the first in its "mind" for subsequent solution. Frank C. Hoyt has joined the Division as Assistant Director of Research and Head of the General and Nuclear Physics Division of the Research Laboratories. Harry W. Kohl has been appointed Division Engineer for the Division's newly created Bay Area Project Division.

• **The Glenn L. Martin Company** and the Drexel Institute of Technology, both in Baltimore, have concluded an arrangement by which any qualified engineer in Martin employed at Middle River may earn an accredited Master's degree in Engineering or Physics while still carrying on normal day-to-day work assignments. J. H. Pond, Martin's Director of Education, said the program "is the culmination of years of serious effort on the Company's part. We feel extremely fortunate in being able to initiate such an outstanding educational opportunity for our people in conjunction with one of the leading engineering institutions in the country." Classes are held from 5:30 to 8 p.m. Mondays through Thursdays. . . . Samuel Storchheim, author of more than 30 technical articles on metallurgical engineering and management, has been promoted to Chief of Manufacturing Engineering and Research in the Company's Nuclear Division.

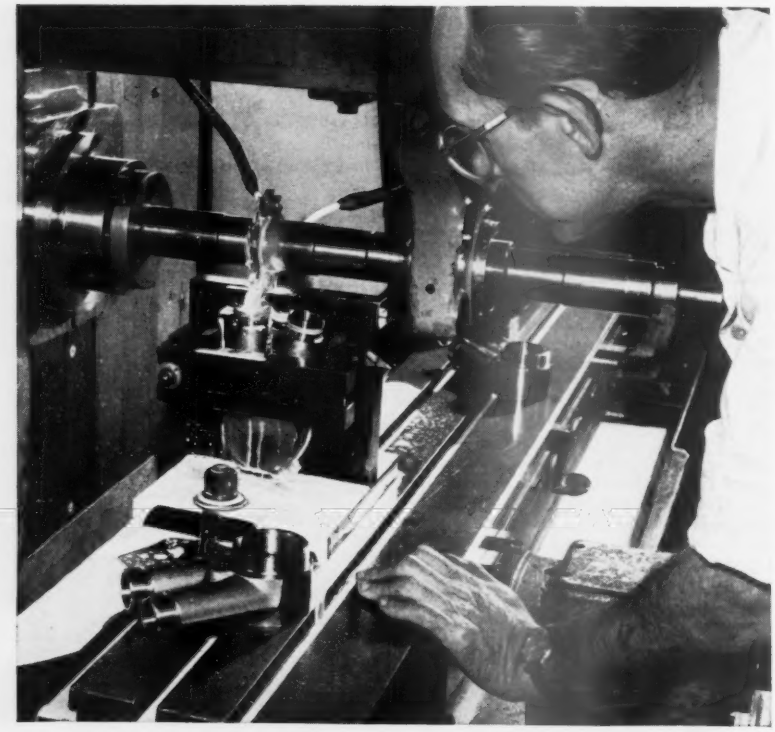
• **Minneapolis-Honeywell Regulator Company** has elected Stephen F. Keating Vice-President. Formerly Vice-President of the Aeronautical Division, Mr. Keating

ITS MOTHER IS A B-29. Lifting a veil of secrecy of several years' duration, the Air Force has announced that this Lockheed Aircraft Corporation vehicle is the X-7, used in development of powerful new engines for USAF ram-jet missiles. Designed and built by the Missile Systems Division, the X-7 flashes through the stratosphere under ram-jet power at speeds well beyond the velocity of sound. Once launched by its mother plane, the X-7 flies on its own, then is recovered by parachute for reuse—an important saving in test-program costs.

This unusual view of the McDonnell RF-101A photo-reconnaissance Voodoo points up the remarkably sleek lines which permit it to knife through the skies at velocities greatly in excess of the speed of sound. Powered by twin Pratt & Whitney J-57 engines, the Voodoo has an extremely long range, permitting accomplishment of supersonic intercontinental reconnaissance missions as a matter of routine.

MALLORY·SHARON reports on

TITANIUM



Now—machine titanium alloys in "soft" condition . . .

HEAT TREAT TO HIGH STRENGTHS

• New heat-treatable titanium alloys can be machined and formed readily, yet offer exceptionally high heat treated strengths in final form.

For example, Mallory-Sharon's MST-6A1-4V titanium alloy is available in the annealed condition with typical ultimate tensile strengths of 140,000 psi. Here machineability is comparable to that of stainless steel. After machining, parts can be heat treated to typical ultimate tensile strength of 185,000 psi.

This is another example of the rapid development of titanium —in which Mallory-Sharon has played a leading role. Call us for the full range of titanium and titanium alloy mill products, and for engineering assistance.

MALLORY-SHARON TITANIUM CORPORATION, NILES, OHIO

MALLORY Ti SHARON

will continue as its head in his new position. Melvin P. Fedders has been elected Division Vice-President and will take charge, as General Manager, of the Division's new $4 million plant to be built near St. Petersburg, Fla. . . . C. Wickham Skinner has been named Director of Administration for the Aeronautical Division's new plant. He has been serving as Chief of Administrative Service for Honeywell's main aeronautical plant in Minneapolis. . . . The Aeronautical Division will supply transistorized fuel-measuring systems for the turboprop Lockheed Electra and Boeing's four-jet 707.

• **Norden-Ketay Corporation . . .** Longer life, greater accuracy, and increased reliability required for industrial application, process industries, systems, and laboratory techniques are claimed for Norden-Ketay's new Bandrive pressure gages. The company reports that the Bandrive movement eliminates backlash and permits accurate calibration over the full dial arc, that parts are under constant load at all times, and that the movement is not affected by rigorous operations conditions. They are made to ASME standards and offer exceptionally long life in pulsating systems where the amplitude indicated by the pointer is under 30 deg. of full scale. A bulletin and additional information may be obtained from the corporation at 99 Park Ave., New York.

• **Northrop Aircraft, Inc. . . .** The Snark SM-62 intercontinental guided missile goes from the Northrop factory at Hawthorne, Calif., to launching sites via a Globemaster C-124 transport, the company and the Air Force have disclosed. The USAF has been using 124's exclusively to deliver Snarks to the Air Force Missile Test Center at Patrick AFB, Fla.

• **Pan American World Airways, Inc. . . .** Capt. Frank M. Briggs, veteran of 18,000 hours who has flown Clippers in Latin America and over both major oceans, has been appointed Chief Pilot of the Latin American Division. He will be in charge of about 500 pilots and will supervise radio officers, dispatchers, and meteorologists, as well as coordinating flight and ground operations.

• **Republic Aviation Corporation** has in operation at its Farmingdale, L.I., plant jet-engine silencers so efficient that ground crewmen can carry on a nearly normal conversation even when engines are operating at full thrust. The basic improvement was found to be "adopters" or couplings which increase the silencing effect. A reduction of 90 per cent in noise is reported.

• **Solar Aircraft Company . . .** An expansion of more than 25 per cent in factory space of the company's Des Moines, Iowa, plant has been approved by the Board of Directors, President Herbert Kunzel has announced. The 117,000 - sq.ft. expansion will be an addition to the Wakonda plant. It is expected that construction will be completed this year.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation** has announced development of a practically-no-drift compass system to ensure precise naviga-

tion on long overwater and polar flights. It was designed in accordance with USAF standards for lightweight instrumentation providing a drift rate of less than 3 deg. per hour. Called the C-10 Gyrosyn Compass, it weighs less than 20 lbs. The five components are master indicator, controller, directional gyro, flux valve, and rack assembly.

• **Stanley Aviation Corporation** has expanded its Denver facility by a 100 per cent addition to its manufacturing area. Increased workload in development of escape systems for the USAF century series' fighters and for naval fighters and bombers has made the new space necessary. Cockpit procedure trainers for Air Force turbine-powered fighters are in production, and new cockpit procedure trainers for Navy jet trainers are in development. The Stanley-designed and manufactured 4 per cent thick wing now is being flown at supersonic speeds on the X-1E research airplane at Edwards AFB.

• **Trans World Airlines** will install the first coast-to-coast electronic reservations network to be used by any air line, according to E. O. Cocke, Senior Vice-President of Sales. It will keep track of seat availability on all flights in advance—domestic for 31 days and overseas up to 6 months. Called Magnetronic Reservisor because of its combination of a magnetic drum for storing information and electronic means of transmitting it, the system was designed to TWA's specification by the Teleregister Corporation.

• **Union Carbide and Carbon Corporation** has announced plans for a new plant for manufacture of fabricated carbon products and has taken an option on a site 4 miles south of Lawrenceburg, Tenn., according to President Morse G. Dial. On completion, the plant will be operated by National Carbon Company, a division of the corporation. About 100 will be employed initially. . . . The problems of high-altitude flight are being studied at the new Parma, Ohio, Basic Research Laboratories of National Carbon. Such flight conditions increase the rate at which "natural" lubricants between brushes and commutator are evaporated. Laboratory Director R. G. Breckenridge reports that addition of extremely small quantities of a special compound may increase brush life several fold. . . . The Division has announced doubling of expansion plans of last April and plans to increase annual productive capacity of carbon and graphite electrode products by more than 100 million lbs. . . . National Carbon has developed a new solid electrolyte battery with unlimited shelf life. It is designed for low-current applications and weighs one fourth of an ounce. It is made primarily of silver, silver iodide, and vanadium pentoxide and consists of 200 paper-thin cells. A continuous current drain of 10-micro-microamp. can be maintained, with flash currents in the micro-ampere range. It is rated at 95 volts. It is suggested that inquiries be directed to E. Sipp, National Carbon Company, 30 East 42nd St., New York.

• **United Air Lines** has introduced at Los Angeles International Airport an automatic baggage self-service system which it claims may revolutionize air-line methods

FIGHT VIBRATION WITH VIBRATION

Shaker system for complex motion tests

NEWEST TECHNIQUE in environmental testing is complex motion testing. It comes closest to reproducing actual vibrational environments encountered in operation of missiles, aircraft, vehicles.

An MB Vibration Exciter System designed for such service is one of optimum versatility. It fulfills not only the special needs of *random motion testing*, but virtually any other test specification as well . . . such as sinusoidal motion testing, fatigue testing, automatic cycling, and provisions of MIL-E-5272A.

HEART OF THE SYSTEM—THE EXCITER

The MB Model C-25HB (shown) is rated at 5000 pounds peak force. Its table assembly is unusually stiff to reduce resonances yet weighs only 75 pounds. Axial resonance lies well over 2000 cps operating range.

This and other MB Exciters for 200, 1200, 1700, 3500, 7000 and 15,000 pound force ratings faithfully reproduce complex wave input signals because their *frequency response* is *flat.*

MATCHED PERFORMANCE

Other elements of the system are integrated with the exciter's high performance. An electronic *amplifier* fulfills the power demands. A control cabinet houses all necessary *instrumentation* plus frequency and amplitude *controls.* Circuits in a *compensation console* give automatic adjustment so that table acceleration remains proportional to input voltages. A top quality tape recorder for playback of the complex wave patterns may be used.

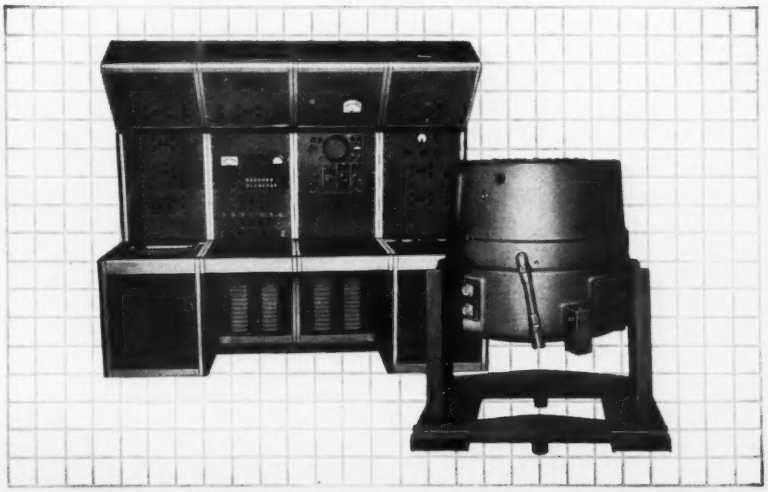
If you have any questions on vibration testing at all, come to a leading authority on the subject . . . the MB engineering staff.

MB *manufacturing company*

A DIVISION OF TEXTRON INC.

1060 State Street, New Haven 11, Conn.

HEADQUARTERS FOR PRODUCTS TO ISOLATE . . . EXCITE . . . AND MEASURE VIBRATION



of delivering passengers' bags at major terminals. The installation consists of two baggage conveyor belts on opposite sides of the claiming area. One is 60 ft. long; the other, 72. Running parallel to each is a diverter which automatically shunts off baggage at 2-ft. intervals. Bags slide down a smooth metal ramp into position for pickup by owners. Inventor is H. C. Warrington, employed at United's Denver Operating Base. . . . R. A. Young, with U.A.L. for 14 years, has been promoted to design manager, Facilities and Property Department, at the company's Chicago headquarters. He is former Superintendent of System Purchasing.

• **United Aircraft Corporation** has announced establishment of the Faye B. Rentschler Scholarship to honor the memory of the wife of the late Frederick B. Rentschler, Chairman of the Corporation until his death last April. Mrs. Rentschler died in 1953. The scholarship will be awarded yearly to a daughter of a corporation employee for the study of engineering or an allied science. Also announced was a second scholarship established in the name of Igor E. Sikorsky, FIAS and member of the AERONAUTICAL ENGINEERING REVIEW Editorial Advisory Committee, who is Engineering Manager of United's Sikorsky Aircraft Division. The two new scholarships bring to eleven the total of U.A.C. scholarships awarded annually to children of employees. . . . Establishment of an Electronics Department by Hamilton Standard Division has been announced by General Manager Erle Martin, FIAS. The move allows the Division to solicit business in the rapidly growing field of aviation electronics over and above the Division's own requirements for its turbine engine and propeller products. The new department will be centralized at Broad Brook, Conn.

• **Vertol Aircraft Corporation** has installed a new high-speed electronic data processing machine at Chester, Pa., for use by engineering personnel. The new "electronic slide rule" is the IBM Magnetic Drum Data Processing Machine. . . . Officials of Vertol and of Weser Flugzeubau, Finanz-und Verwaltungs-Gesellschaft, Bremen, Germany, have jointly announced signing of a licensee agreement covering maintenance, overhaul, and repair of H-21 type helicopters located in Europe. The work will be handled by one of the two plants of the Weser organization at Lemwerder and Einswarden. . . . Vertol, and the Department of the Army, have announced that two Army pilots flying a H-21C helicopter set a new world helicopter record for distance in a closed circuit without pay load on August 11. They flew 1,199.07 miles nonstop in 11 hours and 58 min. The old mark was 778.3 miles in a French SE 3-120 helicopter, set on July 2, 1953. The pilots were Lt. Col. Harry L. Bush, TMIAS, and Major William C. Dysinger. The former is Director Test Division, Board No. 6, Continental Army Command, Fort Rucker Ala. They took off from Trenton-Robbinsville Airport, Heightstown, N.J., at 3:20 a.m. on August 11, and flew a prescribed 85.6-mile course between Heightstown and Haddonfield, N.J., 14 times and landed again at the same airport at 3:20 p.m. Three extra 300-gal. fuel tanks were installed in the cargo compartment, putting fuel at take-off at 1,016 gal. On landing, about 50 gal. remained.

Lt. Col. Harry L. Bush, USA, TMIAS, *left*, and Major W. C. Dysinger express mutual congratulations after they set a new world helicopter record.

• **Vickers Incorporated . . .** Departmental reorganization and appointment of two aides has been announced by Duncan Gardiner, Director of Research and Development. Gerhard Reethof has been named Chief of Research under Mr. Gardiner. LeRoy D. Taylor is the new Assistant Chief Engineer for Development. . . . K. R. Herman, Vickers' President, has announced the appointment of E. L. Burkhart as Personnel Director.

• **Weber Aircraft Corporation . . .** C. E. Heimstadt, General Fabrication Foreman for the last 5 years, has been named Plant Superintendent. . . . Sol W. Voorhes, former head of his own firm of sales consultants who joined Weber in 1955 as Assistant to the President, has been appointed Director of Commercial Sales by President E. K. Meredith. . . . The Commercial Division and the Engineering Department now occupy their own quarters in a newly completed building adjacent to the firm's Burbank, Calif. headquarters.

• **Westinghouse Electric Corporation . . .** Building plans which will add 70,000 sq. ft. of floor space to the corporation's Air Arm Division, Baltimore, have been announced by S. W. Herwald, Division Manager. Need for the expansion has increased by steady growth in Air Arm employment. Dr. Herwald listed a hike in total employment of 1,200 persons in the last 6 months and said employment is expected to double within a 2-year period.

IAS SECTIONS

Meet Your Section Chairman

T. L. K. Smull

Washington Section

Thomas Leland K. Smull, Chief of Research Coordination, NACA, is Chairman of the Washington Section for 1956–1957. An Associate Fellow of the Institute, Dr. Smull was the Section's Vice-Chairman last year and has been active since its formation in the early forties on various committees.

Dr. Smull has devoted considerable time over a period of years to the aircraft noise problem and served as Chairman of the first session at an annual IAS meeting devoted to this problem in January, 1955.

More recently, Dr. Smull served as chairman of a session discussing noise suppression and also as moderator of a panel discussion at the Second International Congress on Acoustics. The Congress was held in June in Boston.

At the IAS National Turbine-Powered Air Transportation Meeting in San Diego in August, Dr. Smull also was chairman of the session devoted to "Noise Associated with Turbine-Powered Transports."

In addition to his interest in the NACA's efforts in the field of operating problems, Dr. Smull's work involves, among other things, the administration of the NACA's contract research program with educational and scientific institutions.

Dr. Smull's 17-year association with the NACA began with his acceptance of a position as Research Engineer at Langley Aeronautical Laboratory, Langley Field, Va.—a post which he relinquished in 1942 to become Assistant to the Director of Aeronautical Research, NACA, in Washington. He was appointed to his present position 4 years later.

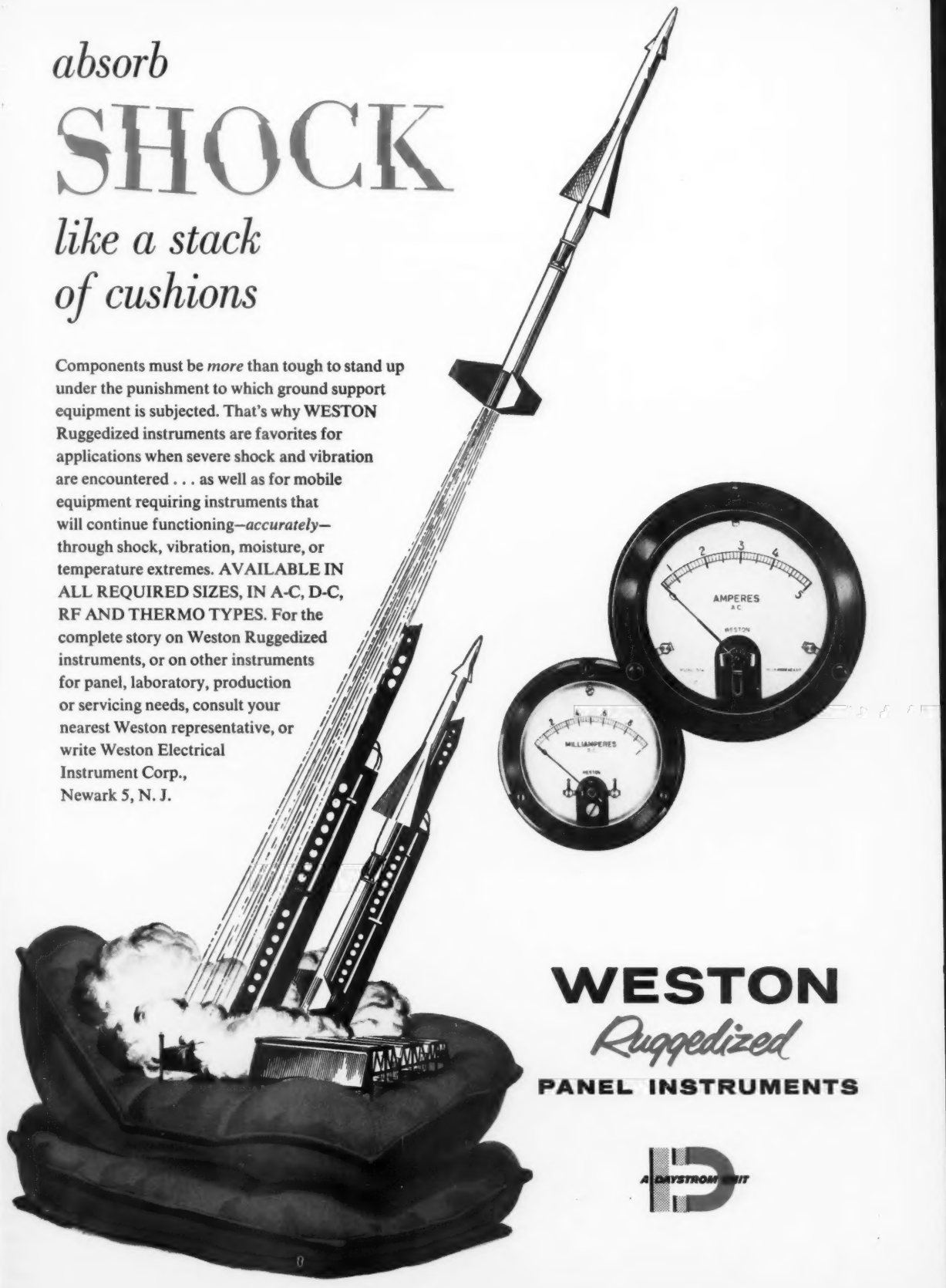
In 1947, Dr. Smull was active on the Staff of the President's Air Policy Commission and the following year was Consultant for Research and Development on the Congressional Aviation Policy Board.

absorb

SHOCK

like a stack of cushions

Components must be *more* than tough to stand up under the punishment to which ground support equipment is subjected. That's why WESTON Ruggedized instruments are favorites for applications when severe shock and vibration are encountered . . . as well as for mobile equipment requiring instruments that will continue functioning—*accurately*—through shock, vibration, moisture, or temperature extremes. AVAILABLE IN ALL REQUIRED SIZES, IN A-C, D-C, RF AND THERMO TYPES. For the complete story on Weston Ruggedized instruments, or on other instruments for panel, laboratory, production or servicing needs, consult your nearest Weston representative, or write Weston Electrical Instrument Corp., Newark 5, N. J.



WESTON

Ruggedized

PANEL INSTRUMENTS

A DAYSTROM UNIT

A registered Professional Engineer in Ohio, Dr. Smull is a member of the Council of the Armed Forces - National Research Council Committee on Hearing and Bio-Acoustics. In addition to the Institute, he holds memberships in the American Geophysical Union and in the Alpha Phi Gamma and Theta Alpha Phi fraternities.

Other organizations in which Dr. Smull is active include the National Aeronautics Association, the Aero Club of Washington, Sigma Phi Epsilon, and the University Club of Washington.

Dr. Smull's writings include *New Horizons in Aeronautical Research—Aviation Annual for 1956* and *Today's Research for Tomorrow's Aircraft—Aviation Annual for 1947*. In addition, he is a contributor to *Collier's Encyclopedia*.

His home is in Washington, D.C.

Columbus Section

Rudolf L. Ranck has been elected Chairman of the Columbus Section for 1956–1957. Other newly elected officers are F. A. Wedberg, Vice-Chairman; Frederick L. Bagby, Jr., Secretary; and Peter L. Marshall, Treasurer. Elected to serve on the Executive Board was Matthew A. Sutton.

J. T. OVERBEY, *Secretary*

Niagara Frontier Section

James A. O'Malley, of Bell Aircraft, has been elected Chairman of the Niagara Frontier Section for 1956–1957. David W. Whitcomb, of Cornell Aeronautical Laboratory, Inc., is new Vice-Chairman.

Other 1956–1957 officers are Ronal B. Crisman, Secretary, and Daniel B. Hardie, Treasurer. Elected to the Advisory Board were Alexander Fla... Robert Goldin, Robert Kelso, Dext... Rosen, George Melrose, and Cliffor... Muzzey, outgoing Chairman.

Philadelphia Section

Earle Stewart, of Vertol Aircra... Corporation, has been elected Chairma... of the Philadelphia Section for 195... 1957. Harold Kaufman, of the Nav... Air Development Center, is new Vic... Chairman.

Marjorie Hecht, of Vertol, was chose... Secretary and Frank E. Mamrol, Jr., ... Piasecki Aircraft Corporation, Trea... urer.

The new Council Board consists ... Capt. Ralph S. Barnaby, USN, Harr... S. Campbell, Louis P. Clark, Robert ... Cotton, Gerald A. Cundiff, Dale Hami... ton, Paul E. Hovgard, John S. Kea... R. H. Prewitt, and Alfred L. Wolf.

MARJORIE HECHT, *Secreta...*

IAS President Edward R. Sharp presents an IAS Letter of Commendation and a Seattle Section plaque honoring W. E. Boeing, Sr., to W. E. Boeing, Jr., *right*, at a banquet in tribute to Boeing Airplane Company and its founder. Looking on is E. C. Wells, who was toastmaster.

Part of a throng estimated at 250 persons who attended the Seattle Section's "Boeing Honors Night" is pictured below in this photo, which also shows the head table.

Boeing Anniversary

Seattle Section

As an estimated 250 banquet gues... looked on, the Seattle Section on Augu... 6 paid tribute to William E. Boeing, Sr... founder of the airplane firm bearing h... name, and observed the company... Fortieth Anniversary. Among honore... guests present in Seattle's Olympic Hot... Spanish Ballroom was the Institute... President, Edward R. Sharp.

On behalf of the IAS Council, D... Sharp presented a Letter of Commend... tion honoring the Boeing Airplane Com... pany founder and, acting for the Se... tion, presented a plaque commemoratin... the firm's anniversary. The elder M... Boeing was unable to attend, and bot... tokens were accepted for him by his so... W. E. Boeing, Jr.

Dr. Sharp, in presenting the plaqu... observed that it was to honor Mr. Boe... ing, Sr., "for his vision in founding a... organization which even in its infanc... was based upon advanced technica... thinking, for his energetic pioneering ... research and development, and for h... establishment of the highest standard... of engineering workmanship."

In addition to Dr. Sharp, others on th... dais who were introduced by Toast... master E. C. Wells, former IAS Vice... President, included Adm. A. M. Bledso... USN, Commandant, Thirteenth Nav... District; Col. W. T. Ensley, USAF, A... Force plant representative; Justice R. ... Ott, Washington Supreme Court, repre... senting Governor Langlie; Councilma... M. B. Mitchell, representing May... Clinton; C. L. Egtvedt, Chairma... Boeing Board of Directors; E. ... Robischon, Manager, Western Regio... IAS; G. W. Taylor, Section Chairma... Mr. Wells also introduced 1956 Secti... officers.

FACTS about NEW DEPARTURE BALL BEARINGS

aircraft turbine bearings...

DESIGNED for HIGH SPEEDS, LOADS and TEMPERATURES

New Departure split inner ring bearing mounting for jet engine main shaft

Today's leading production jet engines turn on New Departure split inner ring bearings . . . an out-ahead development of New Departure's continuing Aircraft Research Program.

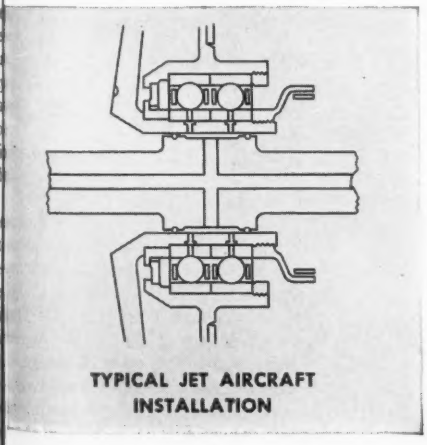
These turbine bearings handle heavy thrust loads from either direction and major radial loads with unexcelled dependability. Two-piece inner ring construction facilitates cleaning, inspection and assembly. It also permits use of the maximum number of balls of largest possible diameter with high thrust shoulders and one-piece separator construction.

While these bearings meet today's demand, tomorrow's needs command the facilities of the New Departure Aircraft Research Program. Already bearing development looks ahead to operational speeds in the order of 100,000 rpm and temperatures close to 1000° F. Write for New Departure's Aircraft Turbine Ball Bearing Folder TB-56. New Departure, Division of General Motors, Bristol, Connecticut.

MEDIUM and LARGE TURBINE BEARINGS

Basic Bearing No.	NOMINAL DIMENSIONS		
	Bore	O.D.	Width
LL34	6.6929	9.0551	1.102
LL36	7.0866	10.2362	1.614*
LL44	8.6614	12.5984	1.929*
L22	4.3307	7.0866	1.280*
L24	4.7244	7.4803	1.280*
L26	5.1181	7.8740	1.280*
L28	5.5118	8.6614	1.574*
L30	5.9055	8.5060	1.235*
L32	6.2992	9.4488	1.338
L34	6.6929	10.6299	1.815*
207	1.3780	2.8346	.669
209	1.7717	3.3465	.938*
212	2.3622	4.3307	.866
213	2.5591	4.7244	.905
214	2.7559	5.1181	1.023
215	2.9528	5.1181	1.181*
216	3.1496	5.5118	1.023
219	3.7402	6.6929	1.259
220	3.9353	7.0886	1.385*
222	4.3307	7.8740	1.771*
224	4.7244	8.4646	1.850*
228	5.5118	9.4488	2.007*
232	6.2992	10.1992	1.660
307	1.3780	3.1496	.826
315	2.9528	6.2992	1.456

*Puller groove, inner ring or both rings



TYPICAL JET AIRCRAFT INSTALLATION

SEE "WIDE WIDE WORLD" SUNDAYS—NBC-TV

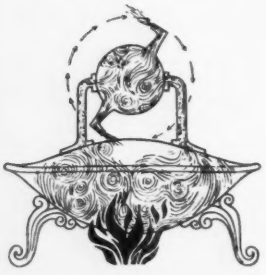
NEW DEPARTURE BALL BEARINGS

GM GENERAL MOTORS

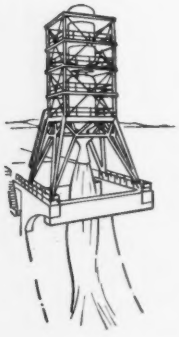
NOTHING ROLLS LIKE A BALL

BALL BEARINGS MAKE GOOD PRODUCTS BETTER

ROCKET POWER



Only yesterday they called it "the art of rocketry." Today, in the first rank of aeronautical science, rocket propulsion is an engineering discipline, an applied technology, and an established industry. The applications for propulsion devices are manifold, the potentialities unbounded.



Aerojet-General Corporation needs men of perspective, inspiration, and practical imagination...To these Aerojet offers unbounded opportunity.

Mechanical Engineers
Electronic Engineers
Chemical Engineers
Electrical Engineers
Aeronautical Engineers
Civil Engineers
Metallurgists
Chemists
Physicists
Mathematicians
Technical Editors

Aerojet-General
CORPORATION
A Subsidiary of The General Tire & Rubber Company
THE GENERAL TIRE
AZUSA, CALIFORNIA
SACRAMENTO, CALIFORNIA

Write: Director of Scientific and Engineering Personnel, Box 296C, Azusa, Calif., or Box 1947C, Sacramento, Calif.

Four Boeing executives each spoke briefly on periods of development within the organization. The speakers and their topics were F. P. Laudan, Vice-President—Manufacturing, "The Start"; L. A. Wood, Vice-President and General Manager—Pilotless Aircraft Division, "Boom Years"; J. K. Ball, Assistant to the Vice-President—Engineering, "War Years"; and G. S. Schairer, Assistant Chief Engineer—Seattle Division, "Jet Age."

Dr. Sharp, after acknowledging honors received over the years by Seattle Section members, presented a biographical résumé of Mr. Boeing, Sr. The Boeing Airplane Company founder, Dr. Sharp said, settled in Aberdeen, Wash., in 1903, conducting timber and logging operations, and then moved to Seattle. It was in the spring of 1915, the speaker recounted, that Mr. Boeing—his appetite for flight whetted by a 1914 or early 1915 flight in a flying boat piloted by Eddie Maroney—visited Los Angeles and there learned to fly at the Glenn L. Martin flying school.

Having bought a seaplane from the Martin school, Mr. Boeing had it shipped to Seattle, and it was there, after he acquired property on Lake Union, that he set about building his own airplane. A friendship between Mr. Boeing and Lt. Comdr. Westervelt, a Naval officer, developed, the two sharing an interest in man's flight, and soon their common desire was to build aircraft as a commercial venture. It was on July 22, 1916, that Pacific Aero Products Company—later changed to Boeing Airplane Company—came into being. The new company's first product was named "B and W," for Boeing and Westervelt. A year later, Mr. Boeing acquired property of the Heath Shipyard on the Duwamish River, moved his company to the site, and started manufacturing in earnest.

Dr. Sharp, pointing out that Mr. Boeing believed in the extreme importance of research and experimentation in the growth and development of his company, told how the determined manufacturer hired two engineering students from the University of Washington. One, Dr. Sharp recounted, was P. G. Johnson, whose death in 1944 cut short the career of a genius in production matters that geared the Boeing firm for its World War II output. The other was C. L. Egtvedt, who today is Chairman of the Board.

Dr. Sharp referred to Mr. Boeing as a "conservative but far-seeing executive . . . one of the leaders in stimulating the logical growth of the aircraft manufacturing industry in America." He concluded by listing other honors that have been received by the elder Boeing and presented the Council Letter and plaque to W. E. Boeing, Jr.

New Section officers, who were to be installed at the September meeting, are L. T. Goodmanson, Chairman; R. E. Bateman, Vice-Chairman; M. E. Kirchner, Treasurer; and T. V. Davis, Secretary.

ELAINE GETHING, *Secretary*

Wichita Section

Jerry H. Gerteis has been elected Chairman and Sanford H. Hinton Vice-Chairman of the Wichita Section. Other new officers, as reported by outgoing Chairman John Ruptash, are Edward J. Sullivan, Secretary; Pink A. Jackson, Treasurer; and C. C. Pearson, Charles K. Razak, Tom Salter, and M. F. Vanik, Advisory Board Members.

STUDENT BRANCHES

The Aeronautical University

Members enjoyed a tour of Chicago's Museum of Science and Industry on August 14.

The group first visited the aircraft section, where various types of aircraft were inspected and members were permitted to study a model of Chicago Midway Airport, including the control tower and radar room.

A member of the museum staff then conducted IAS student members through the German submarine U-505, which was captured by the U.S. Navy in 1944.

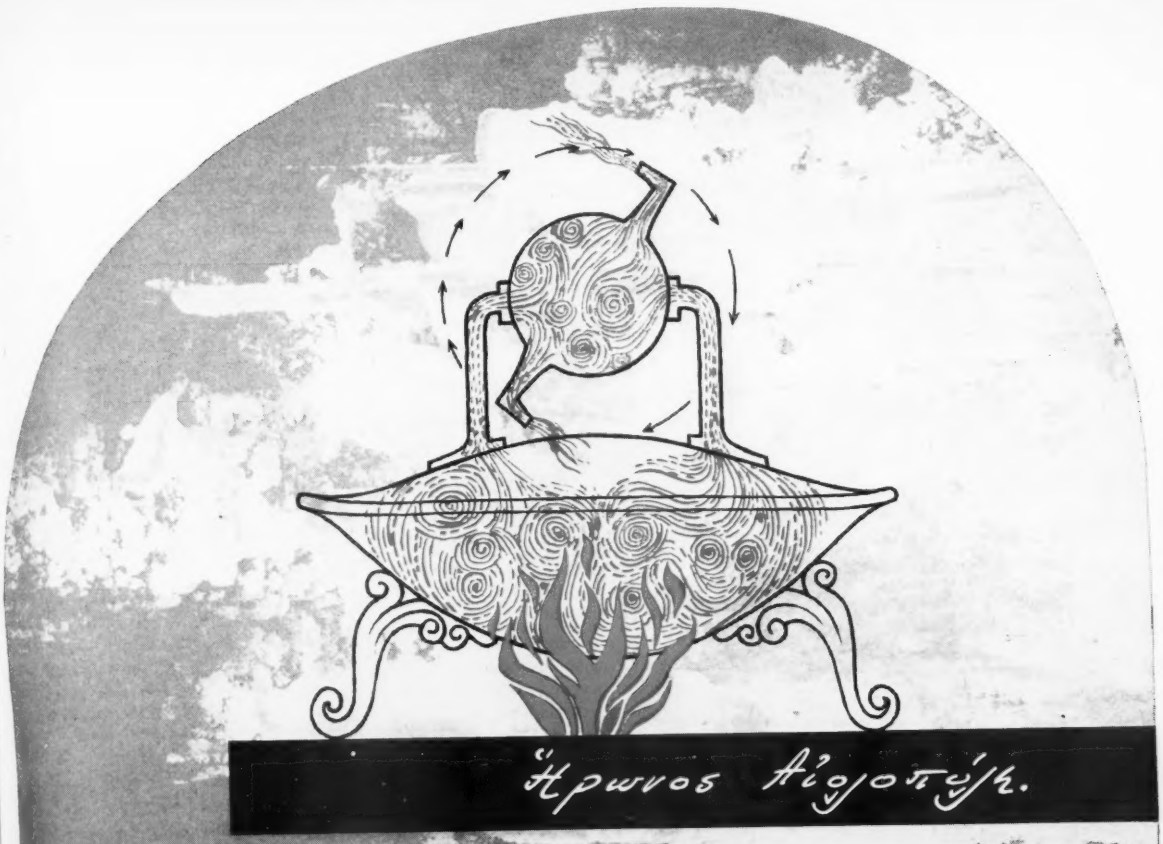
A picnic at the Lake Forest Preserve wound up an extremely interesting day.

SCOTT F. HOO, *Secretary*

Institute of Technology, USAF

An estimated 50 members, faculty, and guests on August 15 gathered in the AFIT Auditorium to hear Lee Devol, Acting Chief of Engineering Physics Research Branch, Aeronautical Research Laboratory, Wright Air Development Center, speak on "Some Aspects of Flight Beyond the Atmosphere."

Primarily, consideration was given to the establishment of an earth satellite for scientific observations. It was shown that guidance and propulsion difficulties in establishing a satellite in a predetermined orbit was of minor magnitude when compared to instrumentation requirements for collection and dissemination of scientific data.



Heron's Aeolipile

In the 3rd Century B.C., 2,000 years before Newton, Heron of Alexandria anticipated modern concepts of jet propulsion with his working model of the aeolipile, a steam-driven forerunner of today's rocket engines.

Heron, Newton, Goddard, von Kármán...the principle endures, the need evolves, the powerplant is born. In our time, Aerojet-General Corporation represents the culmination of research, development and manufacturing in rocket propulsion.

Aerojet-General CORPORATION

A Subsidiary of The General Tire & Rubber Company

THE GENERAL TIRE

AZUSA, CALIFORNIA
SACRAMENTO, CALIFORNIA

Engineers, scientists...at Aerojet-General your opportunity for creative expression is bounded only by the limits of your imagination.

Satellite power requirements while on orbit were evaluated, illustrating current impracticality of nuclear energy for this purpose, as well as the satellite orientation problem faced in the prospective use of solar power.

Problems of lunar and interplanetary rocket travel then were considered. The hypothetical, as well as the established, physical and psychological hazards to such flight were enumerated. Also discussed were various proposed flight schemes, such as the utilization of lunar fueling stations for interplanetary trips.

Dr. Devol was confident—despite the vast number of complex problems presented—that intensive scientific research being conducted will bring about an eventual conquest of the nearer regions of the solar system.

LT. A. A. JANCAUSKAS, *Secretary*

U.S. Naval Postgraduate School

At a meeting on August 22, about 25 members and guests in the School's Compressibility Laboratory heard Prof. Richard M. Head, of the Department of Aeronautics, discuss the Lab's test facilities.

After a discussion and inspection of the transonic tunnel (4 by 16 in., 0.4 to 1.4 *M*) and the supersonic tunnel (4 by 4 in., 1.4 to 4.0 *M*), Professor Head conducted a blowdown run of the supersonic tunnel at a Mach Number of 2.8. An optical display system was used to project the schlieren shadow pattern to a large classroom screen.

During the business meeting, 1956–1957 officers were elected. They are Lt. John C. McCoy, USN, Chairman; Capt. William C. Roberts, Jr., USMC, Vice-Chairman; Lt. (j.g.) James F. McNerney, USN, Secretary-Treasurer; and Lt. George E. Jessen, USN, Corresponding Secretary.

Professor Head continues as Honorary Chairman and Adviser.

University of Virginia

Dean Weihe has been elected Chairman for 1956–1957 and Dayton Brown, Jr., Vice-Chairman. Other newly elected officers are Jack Haley, Secretary, and Robert Mitchell, Treasurer.

Jaime Alexander, former Chairman, has received the IAS Scholastic Award. Two honors have gone to James Sieling. He received the IAS Lecture Award for his talk earlier in the year on "Area Rule" and won a $10 honorarium for the best Open House Project in the Aeronautical Department.

At a recent meeting, members heard a talk on "Testing to Military Specifications," which concerned problems due to apparent inconsistencies of physical laws. The speaker, Mr. McLean, was a representative of Dayton T. Brown, Inc.

Among problems cited by Mr. McLean was that of unwanted release of wing tanks of an aircraft—an occurrence caused by wing vibrations at such a frequency as to activate the controlling relays.

ALLAN D. SUMMERS, *Secretary*

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Gabriel, David S., B. of M.E., Assoc. Chief, Engine Research Div., NACA (Cleveland).

Gunkel, Robert J., M.S.Ae., Chief, Missiles Aerodynamics Sect., Douglas Aircraft Co., Inc. (Santa Monica).

Winter, John S., B. of Ae.E., Chief Engr., Power Plants, Marquardt Aircraft Co.

Transferred to Associate Fellow Grade

Douglas, Leon L., V-P—Engrg., Vertol Aircraft Corp.

Elected to MEMBER Grade

Altman, Samuel P., B. of M.E., Sr. Scientist, Armour Research Foundation of Illinois.

Arnow, Herbert I., B.S.M.E., Aero. Proj. Engr., BuAer Rep., Grumman Aircraft Engineering Corp.

Blantz, Robert J., B. of C.E., Struct. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Bodner, Sol R., Ph.D., Sr. Scientist, Avco Research & Advanced Development Div. (Stratford).

Branchflower, Dale R., M.S., Staff Engr., Missiles Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Brittenham, Edward A., Jr., M.S., Asst. Chief Engr., Goodyear Tire & Rubber Co., Inc.

Burrus, George J., III, B.S. in M.E., Equipment Engr., Lockheed Aircraft Corp. (Marietta).

Chao, Wai W., Sc.D., Staff Engr., Design, Ford Motor Co.

Cockel, Lowell C., Jr., B.S., Proj. Engr., Sandberg-Serrell Corp.

Covell, Dexter O., Jr., B.S. Patent Admin., Sikorsky Aircraft Div., United Aircraft Corp.

Demuth, Orin J., M.S. in Aero., Devel. Engr., Aerojet-General Corp. (Azusa).

Eastwood, Norton R., A.A., Design Specialist, Douglas Aircraft Co., Inc. (Long Beach).

Ericsson, Lars-Eric, Civilingenjör, Wind Tunnel Test Engr. "A," Lockheed Aircraft Corp. (Burbank).

Fortner, Marion J., B.S., Aero. Engr., Board Nr. 6, CONARC.

Greenwood, Robert B., M.S., Aircraft Proj. Officer, USN.

Harris, Frederick, E.E., Manufactures Rep., Wright Patterson AFB (Ohio).

Hartman, John L., Ph.D., Tech. Engr., ANP Dept., General Electric Co. (Cincinnati).

Hartmann, Melvin J., B.S.M.E., Sect. Head, Compressor Research Branch, Lewis Flight Propulsion Lab., NACA.

Hoffman, Sidney, M.S. in E.E., Sr. Aerophysics Engr., Convair, Ft. Worth, A Div. of General Dynamics Corp.

Howell, Sidney C., M. of Indus. & Management Engrg., Eastern Sales Mgr., Aviation Div., The Weatherhead Co.

Huben, Michael G., Prelim. Design Engr., Northrop Aircraft, Inc.

Jephcote, Edwin C., Sr. Design Engr., Lockheed Aircraft Corp. (Marietta).

Johnson, Robert R., Ph.D.M.E., Research Engr., Lockheed Aircraft Corp. (Van Nuys).

Joseph, Alan, B.S. in M.E., Aviation Systems Engr., Specialist, General Electric Co. (Schenectady).

Knaur, John S., Jr., B.S. in Ae.E., Sr. Design Engr., Convair, Ft. Worth, A Div. of General Dynamics Corp.

Koontz, Lyle E., B.S.E.E., Sals Engr., General Electric Co. (Wichita).

Kumbula, Adolph E., B.S., Asst. Supvr., Struct. Engr., Douglas Aircraft Co., Inc. (Tulsa).

Machlanski, Sigmund, B.S.M.E., Head, Controls Dept., Aerojet-General Corp. (Azusa).

Magson, John, Sr. Systems Engr., Computing Devices of Canada, Ltd. (Ottawa).

Manning, James H., Comdr., Admin. Mgr., USN (Jacksonville).

Mason, Edward H., B.S., Experimental Engr., Allison Div., General Motors Corp. (Indianapolis).

Moore, Web W., B.S., Proj. Engr., Cessna Aircraft Co.

Ness, Dale V., B.S. in E.E., Specialist, Product Planner, General Electric Co. (Utica).

Pennell, Howard Y., B.S., Proj. Engr., Electric Coat Div., General Dynamics Corp. (Groton).

Perry, Robert R., Chief Aircraft Performance Engr., Hq., Continental Div., MATS, USAF (Kelly AFB).

Quinn, Carey K., B.S., Sales Engr., AGT Div., Westinghouse Electric Corp. (Washington).

Roderick, Hobart C., B.S. in Engrg. Physics, Dynamics Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Schleich, Grant W., M.S. in Indus. Engrg., Sales Rep., Sperry Gyroscope Co. (Great Neck).

Silvester, Gordon M., Sr. Design Engr., Auster Aircraft Ltd.

Solomon, George E., Ph.D. in Aero. & Physics, Asst. Dir., Guided Missiles Research Div., The Ramo-Wooldridge Corp.

Sutton, James F., M.S.E., Thermodynamics Engr., Lockheed Aircraft Corp. (Marietta).

Thomas, William S., B.S. in Ae.E., Applications Engr., Turbomotor Div., Curtiss-Wright Corp.

Tobak, Murray, M.S. in Engrg. Sci., Aero. Research Scientist, NACA (Moffett Field).

Wood, Robert M., Ph.D. in Ae.E., Research Aerodynamicist, Douglas Aircraft Co., Inc. (Santa Monica).

Wooton, James C., M.S. in Ae.E., Comdr., USN.

Wynn, Francis X., B.S. in E.E., Sales Engr., Aero. Engineering Div., The Garrett Corp. (Indianapolis).

Varley, Joseph G., B. of A.E., Gen. Supvr., Missile Flight Test, Northrop Aircraft, Inc.

Vaughan, Robert C., Sr. Engr., Cook Research Labs. Div., Cook Electric Co.

Yakal, Joseph P., M.E., Test Engr., Douglas Aircraft Co., Inc. (El Segundo).

Zak, Stanley J., V-P, Greenleaf Manufacturing Co.

Transferred to MEMBER Grade

Johnson, Paul G., B.Ae.E., Aero. Research Scientist, Cycle Analysis Sect., Lewis Flight Propulsion Lab., NACA (Cleveland).

Lively, Edith H., M.S., Admin. Asst., Engrg., Lockheed Aircraft Corp. (Marietta).

Mueller, James N., B.S.A.E., Aero. Research Scientist, NACA (Langley Field).

Rosenfeld, Howard M., B.S. in Ae.E., Sect. Head, Production Models Div., Engrg. Dept., Wright Aeronautical Div., Curtiss-Wright Corp.

Elected to Associate Member Grade

Cundiff, A., B.S.M.E., Aviation Sales Engr., General Electric Co. (Phila).

Gotzi, Michael F., Engr. Dwg. Checker, Douglas Aircraft Co., Inc. (Long Beach).

Holmes, George B., B. of Journalism, Service Analyst, North American Aviation, Inc. (Downey).

Maxion, Donald R., Field Service Engr., Consolidated Vultee Aircraft Corp.

Sonne, Fred T., Pres., Chicago Aerial Industries.

Wellman, Fred, Sales Engr., Boots Aircraft Nut Corp.

Elected to Technical Member Grade

Cappelen, Albert L. Jr., B.S., Flight Test Engr., Convair, San Diego, A Div. of General Dynamics Corp.

SIZE 8 (R1000 Series)

.750 x 1.240 inches, weighs 1.75 oz. Available as transmitters, control transformers, resolver and differentials. Max. error from EZ 10 minutes.

SIZE 11 STANDARD (R900 Series)

1.062 x 1.766 inches, weighs 4 oz. Available as transmitters, control transformers, repeaters, resolvers and differentials for 26V and 115V applications. Max. error from EZ 10 minutes.

SYNCHROS

STANDARD AND SPECIAL

SIZE 11 SPECIAL (R500 Series)

Same basic dimensions and applications as standard Size 11 Synchros. Conforming to Bu. Ord. configurations with max. error from EZ of 7 minutes.

PRECISION RESOLVER (R587)

Size 15. With compensating network and booster amplifier, provides 1:1 transformation ratio, 0° phase shift, 5 minute max. error from EZ.

"PANCAKE" SYNCHROS

2.478 x 1.078 inches, weighs 11 oz. Available as transmitters, control transformers, resolvers, differentials and linear induction potentiometers. Max. error from EZ 2½ minutes. Suitable for gimbal mounting.

All these Kearfott Synchros are constructed of corrosion resistant materials, thus enabling them to be operated under adverse environmental conditions.

ALL PHOTOS 3/4 SIZE

KEARFOTT COMPONENTS INCLUDE:

Gyros, Servo Motors, Servo and Magnetic Amplifiers, Tachometer Generators, Hermetic Rotary Seals, Aircraft Navigational Systems, and other high accuracy mechanical, electrical and electronic components.

Send for bulletin giving data of Counters and other components of interest to you.

KEARFOTT COMPANY, INC., Little Falls, N. J.

Sales and Engineering Offices:
1378 Main Avenue, Clifton, N. J.
Midwest Office:
188 W. Randolph Street, Chicago, Ill.
South Central Office:
6115 Denton Drive, Dallas, Texas
West Coast Office:
253 N. Vinedo Avenue, Pasadena, Calif.

Kearfott
A SUBSIDIARY OF GPE

Eakin, Phyllis R., B.A., Assoc. Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Grubensky, John A., B.S.C.E., Designer, Douglas Aircraft Co., Inc.

Jackson, Roy F., Design Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Lutz, Robert H., M.S. in Bus. Admin., Stress Engr., McDonnell Aircraft Corp.

Stiefel, William R., B.S. in M.E., Detail Engr., Allison Div., General Motors Co. (Indianapolis).

Zwieback, Edgar I., B.S., Assoc. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Transferred to Technical Member Grade

Abdalla, Kaleel, B.S. in Ae.E., Aero. Research Scientist, Lewis Flight Propulsion Lab., NACA.

Allen, Harry D., B.S. in Ae.E., Assoc. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Andrews, John F., B.S. in Ae.E., Devel. Engr., Rocketdyne Div., North American Aviation, Inc.

Annenberg, Martin, B.Ae.E., Assoc. Engr., The Glenn L. Martin Co.

Barker, Owen C., B.S.M.E., Mech. Engr., Hughes Aircraft Co.

Bauman, Robert E., B.A.E., Assoc. Engr., Northrop Aircraft, Inc.

Baumgarten, Michael F., B.S. in Ae.E., Aerodynamicist, Grumman Aircraft Engineering Corp.

Berry, Jacob E., Jr., B.S., Field Service Engr., AC Spark Plug Div., General Motors Corp.

Boribhandi, K. J., M.S. in Ae.E.

Bott, Norman, B. of Ae.E., Assoc. Engr., Flight Test, Lookheed Aircraft Corp. (Burbank).

Brovetto, Ronald L., B.S. in Ae.E., Assoc. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Campbell, George S., Ph.D. in Aero., Member of Tech. Staff, Guided Missiles & Electronics, Hughes Aircraft Co.

Chapman, James W., B.S. in Ae.E., Struct. Engr., Convair, Ft. Worth, A Div. of General Dynamics Corp.

Chin, Jimmie, B.S., Assoc. Engr., Aerodynamics, Northrop Aircraft, Inc.

Cincotta, Thomas A., B.S.E., Engr. (Aircraft), North American Aviation, Inc. (Los Angeles).

Cocuzza, Augustus V., B.S. in Ae.E., Assoc. Engr., Lockheed Aircraft Corp. (Burbank).

Colliton, Ronald I., B.S. in Ae.E., Aero. Engr., North American Aviation, Inc. (Los Angeles).

Cooper, Stuart A., B.Ae.E., Ens., USNR.

Cortright, Wendell S., B.S., Assoc. Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Cox, Joe F., B.S. in A.E., Aerodynamics Group Engr., Cessna Aircraft Co. (Wichita).

Cunningham, Don B., B.S., Jr. Engr., Stress Analysis, Chance Vought Aircraft, Inc.

Dettmering, Herbert O., B.A.E., Aerodynamicist, Northrop Aircraft, Inc.

Diamant, Louis W., B. Aero. E., Aerodynamicist, North American Aviation, Inc. (Los Angeles).

Dighton, Robert D., B.S., Jr. Engr., Flight Test Dept., McDonnell Aircraft Corp. (St. Louis).

Dobbertien, Frank M., B.S. in Ae., Engr., Eaton Mfg. Co.

Edwards, Robert W., M.S. in Ae.E., Stress Analyst, McDonnell Aircraft Corp.

Fahrenholz, Fred E., S.B., Research Engr., Naval Supersonic Lab. (Cambridge).

Fuentes, Ronald W., B.A.E., Assoc. Engr., Convair, Ft. Worth, A Div. of General Dynamics Corp.

Gage, Roy C., B.S. in Ae.E., Lt., USAF.

Garnholz, Maurice H., B.S., Research Engr., Rocketdyne Div., North American Aviation, Inc. (Canoga Park).

Geiger, Robert K., M.S. in Ae.E., Proj. Engr., USN VX-1 (Key West).

Goldman, Alfred M., Jr., M.S., 2nd Lt., USAF (Baltimore).

Gongloff, Harold R., B.S. in Ae.Sci., Assoc. Engr., Dynamics Sect., The Glenn L. Martin Co.

Goodin, Carl W., B.S., Liaison Engr., Rohr Aircraft Corp. (Chula Vista).

Green, Allen, B.S., Assoc. Engr., Plant I, Convair, San Diego, A Div. of General Dynamics Corp.

Griffith, Albert W., B.S., Assoc. Engr., Research, Lockheed Aircraft Corp. (Burbank).

Hanley, Donald L., B.S. in Ae.E., Assoc. Engr., Douglas Aircraft Co., Inc.

Harry, David P., III, B.S.M.E., Aero. Research Scientist, Lewis Flight Propulsion Lab., NACA (Cleveland).

Hartsfield, John L., B.S. Ae.E., Assoc. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Hartunian, Richard A., Ph.D., Assoc. Aero. Engr., Cornell Aeronautical Laboratory, Inc.

Hayden, William D., B.S.A.E., Aerodynamics Engr., Convair, Ft. Worth, A Div. of General Dynamics Corp.

Hemings, Robert M., Jr., B.S., Lt. (j.g.), USN; Naval Aviation and Flight Instructor (Pensacola).

Hill, Thomas D., B.S., Test Engr., Pratt & Whitney Aircraft Co. (East Hartford).

Hinman, Kenneth R., B.S., in M.E., Aerodynamics Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Holcombe, Pier, B.S. Ae.E., Graduate Asst., Ordinance Research Lab. (State College, Pa.).

Hoult, Charles P., B.S. in Ae.E.

Howard, Harold W., Ae.E., Structural Loads Engr., WADC, W-P AFB.

Howard, Henry C., Major, USAF; Staff Asst. R&D, Air Defense Group, USAF (Pentagon).

Hutchinson, Samuel R., B.S. Ae.E., Engr., R&D, Aerodynamics, North American Aviation, Inc. (Columbus).

Jaslow, Howard, B.A.E., Aero. Engr., North American Aviation Inc. (Los Angeles).

Johnson, Benford H., B.S. in Ae.E., Engr., Aerodynamics, North American Aviation, Inc. (Columbus).

Jones, Donald L., B.S., Research Engr., Guided Missiles, North American Aviation, Inc.

Jones, Everett, B.A.E., Assoc. Scientist, Missiles Div., Lockheed Aircraft Corp. (Palo Alto).

Kelder, Samuel L., B.S., Assoc. Engr., Design, Lockheed Aircraft Corp. (Burbank).

Kendron, James H., B.S. in E.E., Electronic Engr., Radiation Lab., Admiral Corp.

Ketcham, Bruce V., M.Ae.E., Assoc. Prof., Aero. Engrg., Univ. of Oklahoma; Consultant, Aeronautical Design & Engineering Co.

King, Gerald E., B.S. in Ae.E.

Krava, Roy A., Jr., B.S. in Ae.E., Assoc. Engr., Flight Test Planning Group, Convair, A Div. of General Dynamics Corp.

Larson, Oliver W., B. Aero. E., Engr., Aerodynamics, North American Aviation, Inc. (Downey).

Laster, Marion L., B.Ae.E., Jr. Engr., Warner Robins Air Material Area.

Leak, John S., B.A.E., Aerodynamics Engr., Lockheed Aircraft Corp. (Atlanta).

Lester, James M., B.S. in Ae.E., Assoc. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Levin, Alan D., B.S. in Ae.E.

Lindeman, Robert W., B.S.A.E., Jr. Engr., Wright Aeronautical Div., Curtiss-Wright Corp.

Lindley, Charles A., Ph.D., Engrg. Specialist, Marquardt Aircraft Co.

Lindsay, E. Earl, B.S., Aero. Engr., McDonnell Aircraft Corp.

Locke, George S., Jr., B.S.M.E., Aero. Research Scientist, Ames Aeronautical Lab., NACA (Moffett Field).

Logan, Guy S., B.Ae.E., Assoc. Engr., Aircraft Design & Manufacture, The Glenn L. Martin Co.

Lord, Paul S., B.S., Member of Tech. Staff, Bell Telephone Labs. (Whippany).

Lyles, Charles H., Assoc. Engr., Vertol Aircraft Corp.

McCaffrey, Raymond J., B.S. in Ae.E., Asst. Stress Engr., Reaction Motors, Inc.

McCuen, Peter A., B.S.

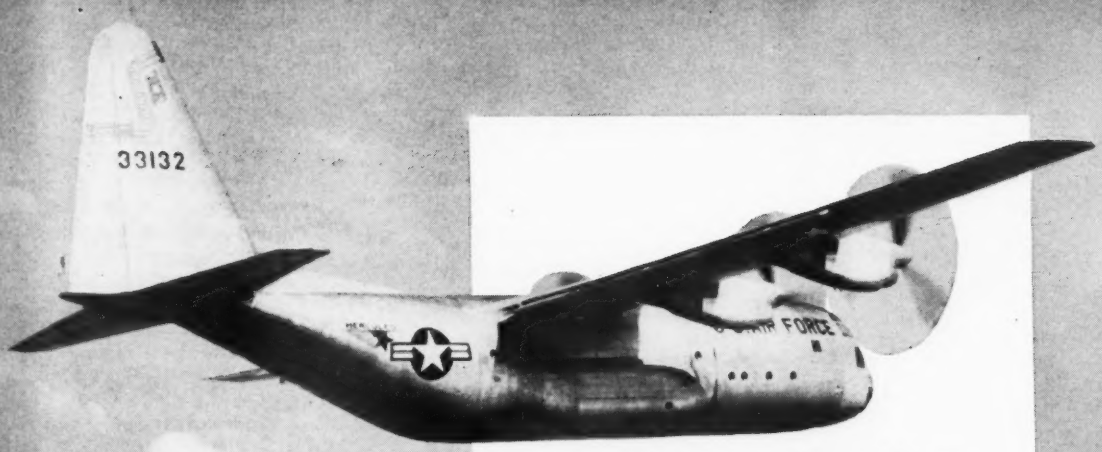
McKinney, Don Dee, B.Ae.E., Assoc. Engr., Lockheed Aircraft Corp. (Georgia Div.).

Mackay, Richard B., Engr., Design, North American Aviation, Inc. (Los Angeles).

Macpherson, Donald F., Jr., B.S. in Aero. E., Assoc. Engr., Flight Test, Lockheed Aircraft Corp. (Burbank).

Mann, Wesley M., Jr., B.S. in Ae.E., Aerodynamics Engr., Convair, Ft. Worth, A Div. of General Dynamics Corp.

HERCULEAN TASK:



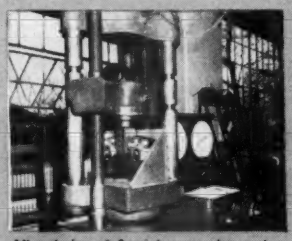
isolating vibration from 15,000 horses

Engine vibrations on the new Lockheed C-130A Hercules turboprop transport are effectively controlled by a LORD-designed Dynafocal® Engine Suspension. As a result, this multi-purpose Air Force combat plane produces greater comfort, safer operation with less structural wear.

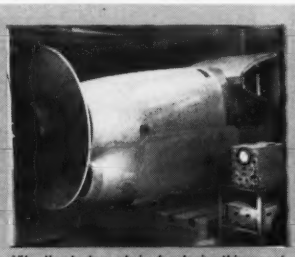
Each of the four Allison T-56 turboprop engines is suspended on a special LORD Dynafocal three-point mounting system. Bonded rubber mountings efficiently isolate vibrations developed by the 3,750 hp powerplants that weigh 2,778 pounds and have a thrust of 8,000 pounds.

Most of our modern aircraft rely on LORD mountings for increased passenger comfort and safety. These mountings are the product of LORD's research and engineering services which are available for the solution of your vibration problem. Call your nearest LORD Field Engineer or write the LORD Manufacturing Co., Erie, Pennsylvania.

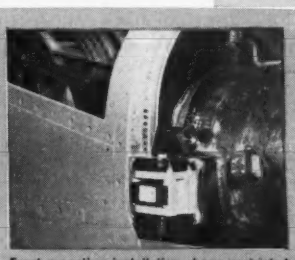
HOW LORD ENGINEERS TACKLED THIS PROBLEM



After design of 3-point suspension system, mountings were subjected to destruction tests on this equipment to determine yield and failure points. Rear mounting illustrated.



Vibration tests made in developing this mounting were performed with an actual Lockheed C-130A nacelle structure.



Front mounting installation shows restricted envelope limitations. C-130A develops 15,000 hp, uses 12 Lord mountings to control engine motion under all load conditions.

NEW YORK, N. Y. - Circle 7-3326 · PHILADELPHIA, PA. - LOcust 4-0147
CLEVELAND, OHIO - SHadyside 9-3175 · DAYTON, OHIO - Michigan 8671
DETROIT, MICH. - TRinity 4-2060 · CHICAGO, ILL. - Michigan 2-6010
DALLAS, TEXAS - Riverside 3392 · LOS ANGELES, CAL. - HOllywood 4-7593
BOSTON, MASS. - HAncock 6-9135
"In Canada—Railway & Power Engineering Corporation Limited"

LORD MANUFACTURING COMPANY, ERIE, PA.

LORD BONDED RUBBER

designers and producers of bonded rubber products since 1924

easiest way to
GRASP
AN IDEA!
NORMA
PEN
ACTUAL SIZE
Yellow or white leads also available.
You work with complex ideas. Do you "see" them quickly enough? You can with the new NORMA Pen and 3-Pencil Combination. It writes in 3 colors of pencil and as a pen . . . gives greater visual clarity . . . saves time! Guaranteed for mechanical perfection by NORMA, makers of quality Multikolor Pencils for over 25 years.
CLICK Black Pencil!
CLICK Blue Pencil!
CLICK Red Pencil!
CLICK IT'S A PEN!
The New
norma
pen and 3-pencil COMBINATION
#604—in Chrome $5.95
INTRODUCTORY Offer: Extra ink refill FREE!
ROY WALKER
If not available at your dealer, order direct from:
NORMA PENCIL CORP., Norma Bldg., Dept. AER
137 West 14th St., New York 11, N. Y.
Please send_____#604 NORMA PEN and 3-PENCIL COMBINATIONS at $5.95 each. I desire them engraved at 50c each.
NAMES FOR ENGRAVING: (please print)
Send information on other models of NORMA —from $5.00 up
I enclose Check Money Order Amt. $_____ (if in N.Y.C. add 3% tax)
NAME_____
ADDRESS_____
CITY_____ZONE No.____STATE_____

Markham, A. L., B.S. in Aero. E., Struct. Engr., Convair, Ft. Worth, A Div. of General Dynamics Corp.

Martucci, Vincent J., B.A.E., Design Engr., Grumman Aircraft Engineering Corp. (Bethpage).

Massey, George R., B.A.E., Assoc. Engr., Northrop Aircraft, Inc.

Maupin, Jimmy G., B.S., Aero. Engr., USAF, Tinker AFB.

Mayben, James E., B.S. in Ae.E., Assoc. Engr., Convair, Ft. Worth, A Div. of General Dynamics Corp.

Mechelay, Joseph E., B. of Ae.E., Assoc. Engr., Northrop Aircraft, Inc.

Metres, Solomon R., B.Ae., Management Analysis Officer, USAF (Fairchild AFB).

Meyrick, Charles W., M.S. in Ae.E., Naval Aviator, Lt., USN.

Miller, Franklin E., B.S. A.E., Engr., General Electric Co.

Miller, Robert D., B.S. in M.E., Mech. Engr., W. E. Burgess & Associates.

Milliken, Walter R., B.S. in Gen. Engrg., Capt., USAF; Instructor (Math.), USAF Academy.

Millman, Lester, B.S. in Aero. E., Engr., Aero. Analysis, Electronics Div., Curtiss-Wright Corp. (Philadelphia).

Minnick, Jack I., B.S. Ae., Jr. Engr. "A," Boeing Airplane Co. (Seattle).

Moeller, John H., M.S.E., Sr. Aerodynamics Engr., Cook Research Labs. Div., Cook Electric Co.

Moore, Rex P., B.S., Assoc. Engr., The Glenn L. Martin Co. (Denver).

Moosbrugger, Charles A., B.Ae.E., Research Engr., Aeronautical Div., Minneapolis-Honeywell Regulator Co.

Moses, Earl L., B.M.E., Assoc. Engr., Aerodynamics, Douglas Aircraft Co., Inc. (Long Beach).

Murray, George H., Jr., B.S., Assoc. Engr., Missile Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Naum, James, B.S. in Ae.E., Aerodynamicist, Grumman Aircraft Engineering Corp.

Neff, William J., M.S., Flight Test Engr., CAA (Washington).

Newcomb, John L., B.S. in Ae.E.

Norman, Wendell S., B.S.M.E., Graduate Asst., Purdue Univ.

Nutant, John, B.S.A.E., Aerodynamicist, Northrop Aircraft, Inc.

Nye, James L., B.S.M.E., Program Engr., Aircraft, Gas Turbines, General Electric Co. (Schenectady).

Oda, Henry, B.S.Ae.E., Assoc. Engr., Design, Lockheed Aircraft Corp. (Burbank).

Okamoto, Paul, B.S. in Ae.E., Assoc. Engr., Northrop Aircraft, Inc.

Ordway, Donald E., Ph.D., Instructor, Graduate School of Aero. Engrg., Cornell Univ.

Overfield, Bert B., Jr., B.S., Engr., Cessna Aircraft Co.

Your
electronic
Problems
receive IMMEDIATE and SPECIAL ATTENTION
in DEVELOPMENT and PRODUCTION of
GUIDED MISSILE Components:
FUEL CUT-OFF RECEIVERS, TELEMETERING
TRANSMITTERS, POWER SUPPLIES FOR BEACONS.
RADAR TEST SETS
SPECTRUM ANALYZERS
SIGNAL GENERATORS
FREQUENCY COUNTERS
And other devices now in production for Army, Navy and Air Forces on prime and sub contracts
MANCHESTER
NEW HAMPSHIRE
NORTHEASTERN ENGINEERING INC.

Oydna, Tunney J., B.S., Asst. Proj. Engr., Naval Ordnance Lab. (Silver Spring).

Patchett, Robert A., B.S., Assoc. Engr. "A," Douglas Aircraft Co., Inc. (Tulsa).

Patton, James McC., Jr., B.S., Flight Test Engr., Chance Vought Aircraft, Inc.

Perciballi, Angelo J., S.B., Research Engr., Massachusetts Institute of Technology.

Peters, Richard M., B.S., Flight Test Engr., North American Aviation, Inc. (Los Angeles).

Prickett, Wayne Z., A.E., Tech. Engr., Aircraft Nuclear Propulsion Dept., General Electric Co. (Evendale).

Pritts, O. Ronald, B.S., Aero. Engr., Gas Dynamics Facility, ARO, Inc.

Rapp, Girard H., B.S., Research Engr., Rocketdyne Div., North American Aviation, Inc.

Reynolds, Robert M., B.S., Service Engr., Douglas Aircraft Co., Inc. (El Segundo).

Richard, Louis P., B.S.M.E., Research Asst., Purdue Univ.

Rittenhouse, Lewis E., B.S., Asst. Proj. Engr., R&D, ARO, Inc. (Tullahoma).

Robinson, Walter P., B.S.A.E., Assoc. Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Rosasco, Giulio J., Weight Engr., Grumman Aircraft Engineering Corp. (Bethpage).

Ross, Charles Richard, B.S. in Ae.E., Assoc. Engr. (Flight Test), Lockheed Aircraft Corp. (Burbank).

Rossettos, John N., M.S., Research Engr., United Aircraft Corp. (East Hartford).

Rubesch, Rudy A., B.A.E., Assoc. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Rueger, Herman A., B.S.M.E., Assoc. Engr., Aerodynamics Sect., The Glenn L. Martin Co. (Baltimore).

Ruth, Edward M., Jr., B.S.M.E., Assoc. Engr., Advanced Design Sect., The Glenn L. Martin Co.

Ryan, Harry J., Jr., Design Trainee, Grumman Aircraft Engineering Corp.

Salvador, Renalds D., B.S., 2nd Lt., USAF; Student Officer Pilot candidate.

Scheno, Vincent J., B.Ae.E., Jr. Test Engr., Curtiss-Wright Corp. (Clifton).

Schneiderman, Gordon R., Assoc. Engr., Northrop Aircraft, Inc. (Hawthorne).

Schoeffel, Peter van R., B.S., Pilot Training, NAS; Lt. (j.g.), USN (Pensacola).

Sheppard, Joseph J., M.S. in Ae.E., Sr. Engr., Univ. of Minnesota.

Sherman, Pauline, M.S., Research Engr., Low Pressure Project, EFS, Univ. of California.

Slater, Myrl L., B.S.M.E., Asst. Engr., Marquardt Aircraft Co.

Smartt, Kenneth D., B.S.M.E. (Aero.), Assoc. Engr., Convair, Ft. Worth, A Div. of General Dynamics Corp.

Smith, John J., Detail Design, Grumman Aircraft Engineering Corp.

Solomon, Hal, B.S. Ae.E., Research Engr., Northrop Aircraft, Inc. (Hawthorne).

Sommer, Fred I., B.S. in Ae.E., Advanced Study Engr., Missile Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Stapleford, Robert L., M.S., Engr., Missiles, North American Aviation, Inc. (Downey).

Stotler, Charles L., Jr., B.S. Ae.E., Engr., Stress, North American Aviation, Inc. (Columbus).

Stowers, John C., B.A.E., Test Engr. "B," Convair, Daingerfield, A Div. of General Dynamics Corp.

Thomas, Roy C., B.M.E., Flight Test Engr., U.S. Naval Air Test Center, U.S. Civil Service (Patuxent River).

Tilgner, Charles, B.S.E.

Todd, James H., Jr., B.S., Assoc. Engr., Product Design Dept., The Glenn L. Martin Co. (Baltimore).

Treneman, Thomas William, B.S, 2nd Lt. and Student Pilot, USAF.

Tulino, Joseph N., B.Ae.E., Design Proj. Engr., Pan American World Airways, Inc. (Miami).

Urbanci, Frank A., B.S., Jr. Aero. Engr., Stress Analysis, Anderson, Greenwood & Co.

Walski, Warren F., B.S., Aerodynamacist "B," Northrop Aircraft, Inc.

Watman, Herbert, B.Ae.E., Aerodynamicist, Grumman Aircraft Engineering Corp. (Bethpage).

Wells, R. Franklin, B. of M.E., Aero. Engr., NACA (Langley Field).

Whitney, William A., B.S.M.E., Asst. Engr., Marquardt Aircraft Co.

Wilkinson, Donald H., B.S.M.E., Asst. Engr., Ram-Jet Engines, Marquardt Aircraft Co.

Wilson, Lionel G., B.S. in Ae.E., Assoc. Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Wilson, Warren S., B.S., Aero. Research Intern, Ames Aero. Lab., NACA (Moffett Field).

Wolk, Anthony E., B.S., Assoc. Engr. The Glenn L. Martin Co. (Baltimore).

Woods, Thomas W., B.S. in Engrg.

Zappa, Oswald L., M.S. in Ae.E., Devel. Engr., Thompson Products.

Zvara, John, A.E., Proj. Engr., Aeroelastic Lab., Massachusetts Institute of Technology.

Twelve Technical Papers Will Be Delivered at CAI-IAS Meeting

(*Continued from page 35*)

Test Flying Session papers will be "The Canadian Test Flying Scene," by Donald H. Rogers, Chief Test Pilot, Avro Aircraft Limited; "Flight Testing of High-Speed Aircraft," by Richard Johnson, Chief Engineering Test Pilot, Convair Division, General Dynamics Corporation; and "RCAF Test and Development," by S/L O.B. Philip, Student, RCAF Staff College, and formerly Chief Test Pilot, Central Experimental and Proving Establishment.

Quality Control Session papers will be "Quality Control Policy in the Royal Canadian Air Force," by G/C Robert McMillan, Chief of Quality Control, RCAF; "Application of Ultrasonic in Aircraft," by Charles P. Albertson, Supervisor of Sonic Testing, and Philip Melara, Supervisor, Quality Control Laboratory, Grumman Aircraft Engineering Corporation; and "Control of Deviating Material," by Harold G. Dickie, Supervisor, Quality Review, Canadian Pratt & Whitney Aircraft Company, Limited.

Electronics Session papers will be "Operational Use of TACAN," by Murray Block, Air Traffic Control Specialist, Federal Telephone and Radio Company, Division of International Telephone and Telegraph Corporation; "A Survey of the Advantages of Transistors in Air-Borne Electronic Equipment," by Earl F. Johnson, Head, Semiconductor Engineering Department, Computing Devices of Canada, Limited; and "Airport and Airways Surveillance Radar for Canadian Air Traffic Control," by Bruce McCaffrey, Project Engineer, Radar Department, Raytheon Manufacturing Company.

Missiles Session papers will be "Guidance and Control of Missiles," by A. G. Carlton, TRITON Division Supervisor, Applied Physics Laboratory, The Johns Hopkins University; "The Technology of Guided Missiles and Its Effect on Industry," by R. D. Richmond, Chief Development Engineer, and J. F. Perrier, Missiles Systems Engineer, Canadair Limited; and "A Method for Evaluating Jet-Propulsion-System Components in Terms of Missile Performance," by R. J. Weber and Roger W. Luidens, Aeronautical Research Scientists, Lewis Flight Propulsion Laboratory, NACA.

Each spot represents an application of MICROJet® pressure ratio controls

VERSATILE MICROJET CONTROLS find many uses on modern high speed aircraft and missiles, regulating a variety of engine functions. Custom-designed Microjet control systems sense and reduce parameters to pneumatic signals, and compute schedules for inlet ramp position, inlet guide vane angle, fuel flow, afterburner ignition or jet nozzle area. Their simple, rugged construction—insensitive to environmental extremes—has been proven on high-performance engines by leading manufacturers. For further information on Microjet controls, address Solar Aircraft Company, Dept. C-87, San Diego 12, California.

SOLAR
AIRCRAFT COMPANY
SAN DIEGO DES MOINES

ENGINEERS WANTED *Unlimited opportunities in Solar's expanding gas turbine program! Write today, giving experience.*

Aeronautical Reviews

A Guide to the Current Literature of Aeronautical Research and Engineering

THIS SECTION reviews important periodicals, technical and research reports, and books received in the IAS Library in order to provide basic documentation for engineers and scientists.

INTERNATIONAL AERONAUTICAL ABSTRACTS, published as an insert in each issue, is an accelerated reviewing service covering worldwide scientific and technical literature. This work is performed by the IAS Staff and is supported by the Air Force Office of Scientific Research of the Air Research and Development Command.

A list of the periodicals and reports series received in the IAS Library is published semiannually, in the January and July issues.

The AERONAUTICAL ENGINEERING INDEX, published since 1947, provides an annual cumulation of the materials reviewed in this section.

THE IAS LIBRARY

Publications reviewed in this section are maintained by the Library for use by the IAS Membership. They are *not* for sale but are made available through the facilities of the Library.

LENDING SERVICES: Institute members, both Individual and Corporate, may borrow periodicals, reports, and books for a period of 2 weeks, excluding time in transit. Excepted are certain reference books and those IAS publications that may be purchased.

PHOTOCOPY SERVICES: The Library is equipped to provide, as a service, positive photocopies of certain materials in its collections. Rates on request.

For detailed information about these and other services, write to:

John J. Glennon, Librarian
Institute of the
Aeronautical Sciences, Inc.
2 East 64th Street
New York 21, New York

PERIODICALS & REPORTS 120
INTERNATIONAL AERONAUTICAL ABSTRACTS. 135
BOOKS 175

Subject Index to Periodicals & Reports

Acoustics, Sound, & Noise 120
Aerodynamics 120
  Aerothermodynamics 120
  Boundary Layer 122
  Control Surfaces 122
  Fluid Mechanics & Aerodynamic Theory 122
  Internal Flow 124
  Stability & Control 126
  Wings & Airfoils 126
Aeroelasticity 128
Aeronautics, General 129
Airplane Design 129
  Air Conditioning & Pressurization 130
  Cockpits 130
  Landing Gear 130
  Operation & Performance 130
Airports 130
Aviation Medicine
  Human Engineering 130
Computers 130
Education & Training 130
Electronics 130
  Amplifiers 133
  Antennas 133
  Circuits & Components 133
  Dielectrics 133
  Navigation Aids 133
  Radar 133
  Semiconductors 133
Equipment
  Electric 133
  Hydraulic & Pneumatic 152
Flight Testing 152
Fuels & Lubricants 152
Gliders 152
Instruments 152
  Automatic Control 152
  Flight Instruments 152
  Flow Measuring Devices 152
  Pressure Measuring Devices 154
  Tachometers 154
  Temperature Measuring Devices 154
  Vibration Measuring Devices 154
Machine Elements 154
  Fastenings 154
Materials 154
  Corrosion & Protective Coatings 154
  Metals & Alloys 154
  Metals & Alloys, Nonferrous 156
  Nonmetallic Materials 156
  Testing 157
Mathematics 157
Meteorology 160
Military Aviation & Armament 160
Missiles 160
Nuclear Energy 160
Photography 160
Physics 160
Power Plants 162
  Jet & Turbine 162
  Ram-Jet & Pulse-Jet 163
  Reciprocating 163
  Rocket 163
Production
  Metalworking 163
  Tooling 164
Propellers 164
Refueling in Flight 164
Rotating Wing Aircraft 164
Safety 165
Space Travel 165
Structures 165
  Bars & Rods 165
  Cylinders & Shells 165
  Elasticity & Plasticity 167
  Thermal Stress 168
Thermodynamics 171
  Combustion 171
  Heat Transfer 171
Vertical Take-Off Aircraft 171
Water-Borne Aircraft 171
Wind Tunnels & Research Facilities 171

Acoustics, Sound, & Noise

Aerodynamic Noise—Cause and Effect. George R. Gibson. *J. GAPAN*, Spring, 1956, pp. 5–10. Discussion of the basic concepts covering perception of sound, frequency and wave length, the decibel and its mathematical definition, attenuation of sound over distance, conversion factors for energy and power units, noise damage to aircraft equipment, physiological phenomena, and the effect of noise on personnel.

Absolute Method for Sound Intensity Measurement. D. R. Pardue and A. L. Hedrich. *Rev. Sci. Instr.*, Aug., 1956, pp. 631, 632.

Acoustic Radiation from a Stationary Cylinder in a Fluid Stream (Aeolian Tones). B. Etkin, G. K. Korbacher, and R. T. Keefe. *UTIA Rep. 39*, May, 1956. 45 pp. 20 refs. Application of Lighthill's equations (for the sound due to body forces) to the flow past a circular cylinder, in order to make quantitative predictions of the directionality and intensity of the sound field and of the total power output. Includes subsonic wind-tunnel tests for providing qualitative experimental verification of theoretical results.

Operational Control of Aircraft Noise at Los Angeles International Airport. Courtland G. Smith. *Noise Control*, July, 1956, pp. 47–55, 80, 81.

Noise Problems in Testing Turbojet Engines. R. O. Fehr. *Noise Control*, July, 1956, pp. 32–36. 10 refs. Discussion taking into account sound attenuation over the transmission path, sound attenuation of the acoustical treatment of the test facility, and tolerance level of the population.

Plant Planning for Noise Control. Nicholas Boratynski. *Noise Control*, July, 1956, pp. 37–46, 95. 30 refs. Investigation to evaluate minimum sound-control requirements for testing Pratt & Whitney PWJ57-P3 and PWJ57-P17 engines.

Aerodynamics

Pressure Distribution and Aerodynamic Properties of High-Speed Aircraft; A Method for Determining the Main Aerodynamic Properties of High-Speed Aeroplanes. Svetopolk Pivko. *Aircraft Eng.*, Aug., 1956, pp. 259–261.

Aerothermodynamics

The Problem of Aerodynamic Heating. E. R. van Driest. (*IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 645.*) *Aero. Eng. Rev.*, Oct., 1956, pp. 26–41. 25 refs. Analysis of the rate of heat transfer to the surface of a high-speed vehicle.

Aérothermodynamique Fondamentale et Notions d'Aérothermochimie. Maurice Roy. *France, ONERA Pub. 84*, 1956. 68 pp. In French. Evaluation of fundamental aerothermodynamics and of principles of aerothermochemistry leading to the derivation of the mechanics of continuous and deformable media.

Quelques Considérations sur l'Exploration Thermique de la Couche Limite et ses Applications. Edmond A. Brun and Max Plan. (*GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.*) *ZAMM*, Sonderheft, Aug., 1956, pp. 8–11. In French. Discussion of the thermodynamic aspect of boundary-layer studies; applications.

A Note on the Effects of Gas Dissociation on Boundary-Layer Heat Transfer. Robert Bromberg. *J. Aero. Sci.*, Oct., 1956, pp. 976, 977. Analysis showing that all effects of dissociation can be characterized by a suitable Prandtl modulus and by the use of the ordinary viscosity of actual gas together with a modified energy potential.

The Effect of Heating and Cooling on the Stability of the Boundary-Layer Flow of a Liquid over a Curved Surface. R. C. Di Prima and D. W. Dunn. *J. Aero. Sci.*, Oct., 1956, pp. 913–916. 12 refs. Investigation of the effects of heat transfer on three-dimensional instability of laminar boundary layers over concave surfaces.

Integral Methods for Laminar Heat-Transfer Calculations. Jacques A. F. Hill. *MIT NSL TR 159*, June 1, 1955. 54 pp. 29 refs. Evaluation of known methods, classified in types according to the assumptions on which they are based, with the results of the evaluation leading to suggestions for reforms.

On Heat Transfer in Laminar Boundary Layers at High Prandtl Number. George W. Morgan and W. H. Warner. *J. Aero. Sci.*, Oct., 1956, pp. 937–948. 25 refs. ONR-sponsored analysis of the asymptotic behavior of the heat transfer in laminar boundary layers.

Mass Transfer Cooling of a Laminar Air Boundary Layer by Injection of a Light-Weight Gas. E. R. G. Eckert, P. J. Schneider, and F. Koehler. *U. Minn., Inst. Tech., Dept. Mech. Eng. TR 8 (OSR TN 56–136)*, Apr., 1956. 24 pp. Velocity, concentration, and temperature field calculations for a laminar boundary layer created by high-velocity, steady two-dimensional air flow with locally uniform pressure and with fluid (hydrogen) injection from the surface. All fluid properties are assumed to vary with local mixture concentration and temperature in the boundary layer.

Temperaturgrenzschichten in dreidimensionalen Strömungen. Dragutin Stojanović. (*GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.*) *ZAMM*, Sonderheft, Aug., 1956, pp. 30, 31. In German. Evaluation of boundary-layer equations for three-dimensional, incompressible laminar flow based on Howarth's approach.

Laminarnyi Pogranichnyi Sloi Szhimaemogo Gaza na Plastine pri Bol'shikh Perepadakh Temperatur. V. V. Lunev. *Prikl. Mat. i Mekh.*, May-June, 1956, pp. 395–401. In Russian. Investigation of the laminar boundary layer over a flat plate, neglecting the simplifying assumptions of the temperature dependence of viscosity.

Ein neues Verfahren zur Bestimmung des Verhältnisses der Austauschkoeffizienten für Wärme und Impuls bei turbulenten Grenzschichten. H. Ludwieg. (*GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.*) *ZAMM*, Sonderheft, Aug., 1956, pp. 21, 22. In German. Development of a method for the determination of the ratio of heat- and impulse-exchange coeffi-

To the ENGINEER of high ability

Through the efforts of engineers The Garrett Corporation has become a leader in many outstanding aircraft component and system fields.

Among them are:

air-conditioning
pressurization
heat transfer
pneumatic valves and controls
electronic computers and controls
turbomachinery

The Garrett Corporation is also applying this engineering skill to the vitally important missile system fields, and has made important advances in prime engine development and in design of turbochargers and other industrial products.

Our engineers work on the very frontiers of present day scientific knowledge. We need your creative talents and offer you the opportunity to progress by making full use of your scientific ability. Positions are now open for aerodynamicists ... mechanical engineers ... mathematicians ... specialists in engineering mechanics ... electrical engineers ... electronics engineers.

For further information regarding opportunities in the Los Angeles, Phoenix and New York areas, write today, including a resume of your education and experience.

Address Mr. G. D. Bradley

THE GARRETT CORPORATION

9851 So. Sepulveda Blvd.
Los Angeles 45, Calif.

DIVISIONS
AiResearch Manufacturing, Los Angeles
AiResearch Manufacturing, Phoenix
AiResearch Industrial
Rex — Aero Engineering
Airsupply — Air Cruisers
AiResearch Aviation Service

TOTAL TEMP. TRANSDUCER
for altitudes to 80,000 ft., temps. from −100F to +350F, de-iced
MACH TRANSDUCER
with range of 0.1 to 3.0 Mach
SENSITIVE ALTITUDE TRANSDUCER
AIRSTREAM DIRECTION TRANSDUCER
with accuracy of 0.1 degree 90 knots to supersonic
ABSOLUTE AND DIFFERENTIAL PRESSURE TYPE TRANSDUCERS
with accuracy to 0.4%
CENTRAL COMPUTER
containing all necessary system mechanization of both electronic and mechanical types
PLUG-IN AMPLIFIER MODULE
utilizing either vacuum tube, mag-amp or transistor
ACCELEROMETER
with accuracy to 0.4% of G
ENGINE PRESSURE RATIO INDICATING SYSTEM
with accuracy of 0.02 ratio units
HIGHLY-EFFICIENT ACTUATORS
to provide mechanical outputs

Finer components mean better air data systems

AiResearch makes transducers, computers and indicators of superior sensitivity and accuracy in *all* required parameters. These can be combined into systems that provide the air data you require and convert it into any desired type of information or impulse. The products shown in the above illustration indicate some of the areas in which we are thoroughly experienced. If desired, we will take complete system responsibility. We invite inquiries to meet the most rigid specifications.

Qualified engineers are needed now. Write for information.

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Designers and manufacturers of aircraft systems and components: REFRIGERATION SYSTEMS • PNEUMATIC VALVES AND CONTROLS • TEMPERATURE CONTROLS CABIN AIR COMPRESSORS • TURBINE MOTORS • GAS TURBINE ENGINES • CABIN PRESSURE CONTROLS • HEAT TRANSFER EQUIPMENT • ELECTRO-MECHANICAL EQUIPMENT • ELECTRONIC COMPUTERS AND CONTROLS

cient in the presence of turbulent boundary layers. The method can be applied to other turbulent boundary-layer flows and to problems of mixing of free turbulence.

Étude Expérimentale de la Convection Forcée sur Paroi Mobile (Hyperconvention Favre). Charles Bory. *France, Min. de l'Air PST 312,* 1956. 70 pp. SDIT, 2 Av. Porte-d'Issy, Paris 15, Frs. 1,000. In French. Study of the heat transfer between the flow of air and a cylinder, whose wall is partially exposed to the wind.

An Inverse Problem in Hypersonic Viscous Flow. Ting Yi Li. *Rensselaer Polytech. Inst. Dept. Aero. Eng. TR AE-5603 (AFOSR TN 56-308),* July 13, 1956. 35 pp. Analysis to determine a body shape from a prescribed pressure field.

Note on the Flow Fields on the Rear Part of Blunt Bodies in Hypersonic Flow. Antonio Ferri and Adrian Pallone. *USAF WADC TN 56-294,* July, 1956. 19 pp. Discussion emphasizing the importance of entropy effects as a function of Mach Number and indicating how these effects increase with Mach Number to achieve considerable significance in the $M = 10$ to $M = 20$ range.

The Boltzmann H-Function Applied to the Shock Transition. Appendix A—**Distribution Function and Integration Formulae.** Appendix B—**Approximations to Boltzmann's H-Function.** Appendix C—**Mathematical Solution of the Shock Transition.** E. L. Harris and G. N. Patterson. *UTIA Rep. 40,* May, 1956. 32 pp. USAF-supported investigation.

Application of Hydraulic Analog Method to One-Dimensional Transient Heat Flow. Eldon L. Knuth and Emerson L. Kumm. *Jet Propulsion,* Aug., 1956, pp. 649–654, 659. Extension of the analogy between one-dimensional transient heat flow and flow of a liquid through a tube to include certain boundary conditions which occur in problems involving aerodynamic heating.

Boundary Layer

Rapid Laminar Boundary-Layer Calculations by Piecewise Application of Similar Solutions. A. M. O. Smith. *J. Aero. Sci.,* Oct., 1956, pp. 901–912. 15 refs. Method for the rapid calculation of the incompressible laminar boundary layer in an arbitrary flow around either a two-dimensional or a rotationally symmetrical body.

Praktische Berechnung von Grenzschichten. Kurt Kraemer. *Luftfahrttechnik,* Jan. 15, 1956, pp. 8–13. In German. Step-by-step evaluation of the Truckenbrodt quadratic equation for calculating the laminar and turbulent boundary layer along smooth and rough nonporous surfaces.

Übersicht über Grenzschichtprobleme. van Nes. *Luftfahrttechnik,* July 15, 1955, pp. 42–47. In German. General survey of boundary-layer problems.

Berechnung der laminaren Grenzschicht mit Absaugung. E. Truckenbrodt. *(GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.) ZAMM,* Sonderheft, Aug., 1956, p. 49. In German. Calculation of the laminar boundary layer with suction, taking into account Schlichting and Torda approximate methods.

Der Einfluss der Vorgänge in der Grenzschicht auf den Ablauf verfahrenstechnischer Prozesse. Walter Barth. *(GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.) ZAMM,* Sonderheft, Aug., 1956, pp. 1–3. In German. Analysis of the influence of boundary-layer research on the development of technical processes.

Priblizhennoe Reshenie Nekotorikh Nestatsionarnykh Zadach Pogranichnogo Sloia. E. M. Dobrishman. *Prikl. Mat. i Mekh.,* May-June, 1956, pp. 402–410. In Russian. Derivation of an approximate solution for certain nonstationary problems of the boundary-layer theory.

Ob Odnom Vidoizmenenii Priblizhennogo Metoda M. E. Shvetsa. L. S. Gandin and R. E. Soloveichik. *Prikl. Mat. i Mekh.,* Mar.-Apr., 1956, pp. 295, 296. In Russian. Analysis and suggested modification of the Shvets method for the approximate calculation of the boundary-layer edge problem.

Ein Äquivalenzsatz für laminare Grenzschichten bei Hyperschallströmung. K. W. Mangler. *(GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.) ZAMM,* Sonderheft, Aug., 1956, pp. 22–24. In German. Analysis of the equivalence law for laminar boundary layers in hypersonic flow.

Näherungstheorie für kompressible turbulente Grenzschichten. A. Walz. *(GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.) ZAMM,* Sonderheft, Aug., 1956, pp. 50–56. In German. Development of an approximation theory for compressible, turbulent boundary layers.

Control Surfaces

The Estimation of the Lift due to Full and Part Span Controls. J. C. Simmons and J. A. Dunsby. *J. RAeS,* Aug., 1956, pp. 545–549.

A Further Discussion on Mixing and the Jet Flap. B. S. Stratford. *Aero. Quart.,* Aug., 1956, pp. 169–183. Analysis of jet mixing by using momentum principles and a quantitative examination of the sink effect. Results show that, in mixing between the main stream and the jet, one aspect, the primary change in thrust, is understood and can be calculated.

Recherches Théoriques et Expérimentales sur le Contrôle de Circulation par Soufflage Appliqué aux Ailes d'Avions. L. Malavard and P. Jousserandot. *France, ONERA TN 37,* 1956. 75 pp. 12 refs. In French. Theoretical and experimental investigations of the circulation control around the airfoil profile by a jet blast oriented accordingly at the trailing edge.

Fluid Mechanics & Aerodynamic Theory

Compressible Fluid Flow. Robert F. Badertscher and Wilbur A. Spraker, Jr. *Battelle Tech. Rev.,* Aug., 1956, pp. 3–16. Review of aerodynamic developments in the subsonic, transonic, and supersonic ranges considering external and internal aerodynamics, viscosity effects, and industrial applications.

A Principle of Maximum Power for Real Fluids in Steady Motion. Carlo Ripabelli. *J. Aero. Sci.,* Oct., 1956, pp. 971, 972. Method for determining the velocity distribution in a fluid using an analogy between this phenomenon and the displacement distribution in an ideal elastic material deformable in shear but having constant volume.

Avtomodelnye Zadachi Neustanovivshegosiia Pogranichnogo Sloia Szhimaemogo Gaza. Iu. A. Dem'ianov. *Prikl. Mat. i Mekh.,* Nov.-Dec., 1955, pp. 760, 761. In Russian. Mathematical formulation of problems of unstabilized boundary layer of an incompressible gas, applicable to the formulation of equations for flow around bodies of revolution, satisfying the conditions $R = cx^n$.

Ein Verfahren zur Untersuchung des Austauschvorganges in verwirbelten Strömungen hinter Körpern mit Abgelöster Strömung. August-Wilhelm Quick. *Nordrhein-Westfalen, Arbeitsgemeinschaft für Forschung, Heft 50,* 1956, pp. 35–67; Discussion, pp. 69–78. In German. Development of a method for studying the mixing process in vortices behind blunt bodies with separated flow.

Osnovy Gazodinamiki Vzaimnoproniknikaiushchikh Dvizhenii Szhimaemykh Sred. H. A. Rakhmatulin. *Prikl. Mat. i Mekh.,* Mar.-Apr., 1956, pp. 184–195. In Russian. Fundamentals of gasdynamics of cross penetration of two compressible media. The formulation of the problem is partly based on a generalization of the Joukowski theory. An equation of motion for an ideal media is formulated, and it is shown that the analogical systems of equations are applicable to viscous and elastoplastic cases.

Ob Asimptoticheskikh Resheniiakh Uravnenii Odnomernogo Neustanovivshegosia Dvizheniia Ideal'nago Gaza i ob Asimptoticheskikh Zakonakh Zatukhaniia Udarnykh Voln. Iu. L. Iakimov. *Prikl. Mat. i Mekh.,* Nov.-Dec., 1955, pp. 681–692. In Russian. Investigation of three types of asymptotic solutions for linear equations of unsteady motion of an ideal gas having spherical symmetry, taking into account Landau, Zel'dovich, and Sedov results. The calculation is performed by using functional series.

Mehrparametrige Zähigkeit als Grundlage einer Quasi-Kontinuumtheorie der Kompressionsfront für mehratomige Gase. J. Theodorides. *(GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.) ZAMM,* Sonderheft, Aug., 1956, pp. 38–46. 44 refs. In German. OSR-sponsored investigation of multiparametric viscosity as basis for a quasi-continuum theory of compression fronts in polyatomic gases.

Viscous Flow Along a Flat Plate Moving at High Supersonic Speeds. Y. H. Kuo. *J. Aero. Sci.,* Oct., 1956, pp. 977, 978. Comparison of Kendall and Kuo results for flow at high supersonic speeds.

Zusammenfassende Darstellung und Erweiterung des Aequivalenzsatzes für schallnahe Strömung. F. Keune. *DVL Bericht No. 8,* July, 1956. 74 pp. 33 refs. Westdeutscher Verlag, Köln & Opladen. In German. Evaluation of available theories and extension of the equivalence law for flow near the speed of sound.

Beitrag zur Berechnung von Sekundärströmungen. E. Becker. *(GAMM, Fachausschuss für Strömungsforschung,*

great step forward in the automation of fuel systems

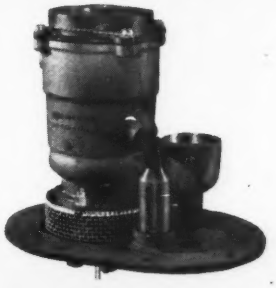
1,200 hour "Dry Run" torture test Proves Reliability of HY-V/L* Fuel Pumps

On September 1, 1956, a HY-V/L fuel pump (Model 60-029) completed 1,265 hours of continuous operation under simulated jet fighter conditions. The test was run in three-hour cycles: one hour "wet run" (submerged in fuel) at sea level, followed by two hours "dry run" (without fuel) at 50,000 feet with 150° F. ambient temperature.

In an earlier test, the HY-V/L pump (Model 60-071) ran "dry" continuously for 18 hours at an altitude of 55,000 feet, simulating conditions encountered in a long-range jet bomber.

In both tests the case temperature of the HY-V/L pump stayed well below the dangerous auto-ignition mark (400° F.). The HY-V/L pump requires no thermal protection, even under a locked rotor condition.

Every Fighter, Every Bomber, Every Transport is Hydro-Aire Equipped



These test results are steps forward in the complete automation of fuel systems. Because the HY-V/L pump requires no thermal protection device, it offers much greater reliability; because it runs "dry" safely, it needs no switch or other shutoff device.

Remember the advantages of the HY-V/L pump: simple... compact... lighter... eliminates the old vapor separator... uses less power... excellent climb performance... recovers immediately... pumps all types of avgas and jet fuels... has "Design Predictability," i.e. it can easily be tailored to your specific needs. Write for complete details.

**High Vapor/Liquid Ratio*

HYDRO-AIRE *Inc.*

3000 WINONA AVE., BURBANK, CALIF.

the aviation subsidiary of CRANE

Also make Fuel Gate Valves, Hot Air Valves, and the "Hytrol" Anti-Skid Braking System.

Tagung, Göttingen, Oct. 7, 1955.) *ZAMM*, Sonderheft, Aug., 1956, pp. 3–8. In German. Contribution to the study of secondary flows.

Experiments on Circular Cones at Yaw in Supersonic Flow. Maurice Holt and John Blackie. *J. Aero. Sci.*, Oct., 1956, pp. 931–936. Investigation on two circular cones, one with a semiapex angle of 15° and the other with an angle of 20°. Pressure measurements are given for angles of yaw up to 25° and for a Mach Number of 3.53.

Kol'tsevoi Vikhr' pri Neustanovivshemsia Dvizhenii. S. M. Belotserkovskii. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1956, pp. 173–183. In Russian. Study of the circular vortex in unstabilized motion, applicable to the problem of circular flow around bodies of revolution.

Obtekanie Tonkikh Tel v Trekhmernom Potoke. M. D. Khaskind. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1956, pp. 203–210. In Russian. Application of the method of potential theory to the study of three-dimensional flow around thin bodies.

Obtekanie Profilei Potokom Dozvukhovoi Skorosti so Sverkhzvukovoi Zonoi, Okanchivaiushcheisia Priamym Skachkom Uplotneniia. F. I. Frankl'. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1956, pp. 196–202. 10 refs. In Russian. Investigation of the subsonic flow with a supersonic zone around profiles, resulting in a sudden rise of condensation.

delavan
NOZZLES
Delavan . . . designer and manufacturer of fuel nozzles for Pratt & Whitney Aircraft's J57 turbojet, powering the Boeing B-52 Stratofortress. Delavan has brought unprecedented nozzle performance to the aircraft industry.
DELAVAN Mfg. Co.
WEST DES MOINES, IOWA

Utochnenie Teorii Prostogo Kraevogo Effekta. A. L. Goldenweiser. *Prikl. Mat. i Mekh.*, May-June, 1956, pp. 335–348. In Russian. Derivation of a more exact representation of the theory for simple boundary effects than that obtained and applied by Staerman, Heckeler, Rabotnov, and Goldenweiser.

Effects of Kinematic Viscosity and Wave Speed on Shock Wave Attenuation. Appendix I—Review of Empirical Relations. Appendix II—Derivation of the Attenuation Function and the π Coefficient. Appendix III—Note on the Use of Constant p_1 in the Constant ν_2 Experiments. Appendix IV—Note on the Application of Non-Stationary, Laminar Skin Friction Coefficients. D. W. Boyer. *UTIA TN8*, May, 1956. 76 pp. 19 refs.

Attenuation in a Shock Tube Due to Unsteady-Boundary-Layer Action. Appendix A, B—Characteristic-Line Geometry and Some Integrals. Appendix C—Interaction of Pressure Waves with Interfaces. Appendix D—Laminar Boundary Layer Behind Wave. Appendix E—Turbulent Boundary Layer Behind Wave. Appendix F—Development of Attenuation Formulas. Appendix G—Ideal Shock-Tube Relations. Appendix H—Reynolds Numbers and Transition. Appendix I—Generation of Pressure Waves by Wall Shear and Heat Addition. Harold Mirels. *U.S., NACA TN 3278*, Aug., 1956. 60 pp.

Die Schallmauer. Gerhard Schulz. *Luftfahrttechnik*, Jan. 15, 1956, pp. 2–7. 10 refs. In German. Analysis of aerodynamic problems including subsonic, transonic, and supersonic phases.

Zur Berechnung der turbulenten Strömung. C. Torre and J. Martinek. (*GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.*) *ZAMM*, Sonderheft, Aug., 1956, pp. 46–48. In German. Calculation of turbulent flow based on the equation of motion and mass law and using finite displacement for the derivation of basic differential equations.

Internal Flow

On a Class of Laminar Viscous Flows Within One or Two Bounding Cones. A. J. A. Morgan. *Aero. Quart.*, Aug., 1956, pp. 225–239. 10 refs. Analysis of a class of incompressible laminar viscous flows in which the component velocities are inversely proportional to the distance from the origin, and which provide exact invariant solutions of the Navier-Stokes equations.

Cascade Investigation of a Related Series of 6-Percent-Thick Guide-Vane Profiles and Design Charts. James C. Dunavant. *U.S., NACA RM L54I02*, Nov. 26, 1954. 48 pp. 12 refs. Description of tests resulting in the selection and use of design angles of attack in a method of determining the camber for guide-vane angles as high as 50°.

Investigations of the Flow Through a Cascade of Blades. I—Experiments on the Vortex Flow Behind Annular Blade Cascades. II—A Theoretical Method of Designing Blade Profiles. N. Scholz. (*VDI-Forschungsheft 442*, 1954, pp. 1–24, 25–48.) *Gt. Brit., MOS TIB/T4540 (A), TIB/T4540 (B).* 36, 49 pp. 29 refs.

Profilne Kaskade. Anton Kuhelj. *Strojniški Vestnik*, No. 4, 1956, pp. 98–103. In Slovene. Outline of the method of conformal representation for flow of non-viscous fluids through airfoil cascades, derivation of fundamental equations for the singularity method, and discussion of the main problems encountered.

Zur laminaren Strömung in einer kreiszylindrischen Dose mit rotierendem Deckel. D. Grohne. (*GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.*) *ZAMM*, Sonderheft, Aug., 1956, pp. 17–20. In German. Study of the laminar flow in a circular cylinder with a rotating cover, taking into account Föttinger results.

Three-Dimensional Flow in Axial-Flow Turbomachinery. III. Leroy H. Smith, Jr. *USAF WADC TR 55-348 (Vol. II)*, Mar., 1956. 9 pp. Determination of the geometry of runner and diffuser vanes from equivalent diagrams, and presentation of previously obtained two-dimensional cascade data.

Über die Geschwindigkeitsverteilung in einer geradlinigen turbulenten Couetteströmung. H. Reichardt. (*GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.*) *ZAMM*, Sonderheft, Aug., 1956, pp. 26–29. In German. Specification of the Couette flow concept and study of the velocity distribution in a rectilinear turbulent Couette flow.

Reshenie Obratnoi Zadachi Ploskogo Kavitatsionnogo Obtekaniia Krivolineinoi Dugi. G. N. Pykhteev. *Prikl. Mat. i Mekh.*, May-June, 1956, pp. 373–381. 17 refs. In Russian. Analysis of the inverted problem of calculating the profile shape according to given velocity distribution, encountered in the projection of turbine blade and pump shaping.

Analysis of Laminar Incompressible Flow in Semiporous Channels. Patrick L. Donoughe. *U.S., NACA TN 3759*, Aug., 1956. 25 pp. Derivation of perturbation solutions of pertinent equations, with results compared to those obtained from a fully porous channel.

Further Comments on the Decay of a Nonuniform Velocity Distribution. William J. Guman. *J. Aero. Sci.*, Oct., 1956, pp. 979, 980. Analysis of the decay in a nonuniform velocity field using the kinetic energy carried by this velocity field as a measure of the nonuniformity.

Novi Postopki za Merjenje Pretoka v Ceveh. Miroslav Pečornik. *Strojniški Vestnik*, No. 2, 1955, pp. 39–42. In Slovene. Derivation of formulas for the evaluation of average flow velocity through pipes, based on general equations for laminar and turbulent flows.

Estimating Ductwork Pressure Losses. *Aircraft Heating Dig.*, Summer, 1956, pp. 1–7. Derivation of curves presenting friction losses in straight ducts, taking into account the friction factor produced by changes in mass flow and equivalent diameter. The curves for elbows assume that the elbow is preceded and followed by a sufficient length of straight duct to establish symmetrical flow within the duct.

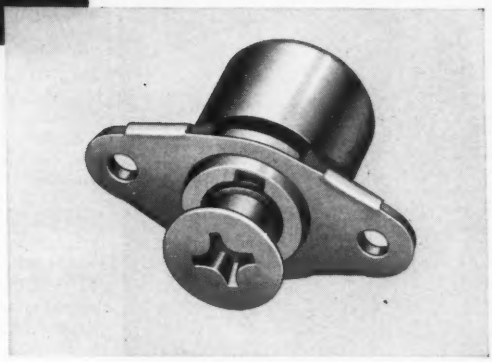
Druckverlust in Rohren nichtkreisförmigen Querschnittes bei hohen Geschwindigkeiten. A. Naumann. (*GAMM, Fachausschuss für Strömungsforschung,*

The *New* Pastushin Full-Shear Stress Panel Fastener does what a panel fastener should do!

- absolute positive lock... full shear strength
- automatic spring ejection of stud... no prying to free panel
- curved panel is no problem
- only two assemblies (self-retained)... stud and retainer
- no special installation tools... Phillips head recess

PATENT PENDING

Available now in quantity!



Fastens and unfastens a panel faster and easier than any other fastener on the market!

Check these important features:

Full Shear Strength... stud design transmits full shear strength equal to NAS-547 specification, and/or NAS 334-335 close tolerance bolt.

Positive Mechanical Lock... when stud is seated, it's locked! Visual inspection assures safe lock.

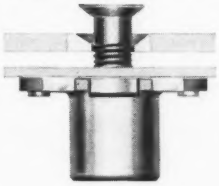
Automatic Stud Ejection... when stud is released, it is automatically spring-ejected from the retainer, allowing panel removal without forcing or prying.

Curved Panels offer no problem...small radius of entry of stud into retainer assembly allows installation and operation on surfaces of less than one inch radius.

Double Lead Stud Thread... assures top performance and trouble-free long service life.

Materials and Finishes ... critical bearing surfaces are of CM steel, heat treated to rigid specifications. Steel parts are cadmium plated, aluminum alloy parts anodized.

This is the actual size of the ¼" fastener assembly ... tiny, lightweight and strong. The 5/16" unit is proportionately larger.



Write for complete information on Pastushin's Full-Shear Stress Panel Fasteners, designed for high-strength and simplified securing of access panels and equipment on modern aircraft.

PASTUSHIN INDUSTRIES, INC.

5651 WEST CENTURY BOULEVARD, LOS ANGELES, CALIFORNIA

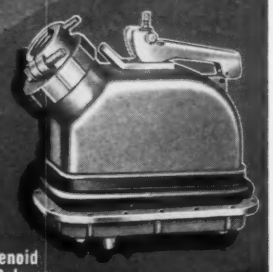
Affiliate Companies

PASTUSHIN AVIATION CORP. Los Angeles, California | **HAWAIIAN AIRMOTIVE, LTD.** Honolulu, Hawaii

DEVELOPERS AND MANUFACTURERS OF AIRCRAFT FASTENERS

40th YEAR

Cannon quality in missile launching connectors means safety

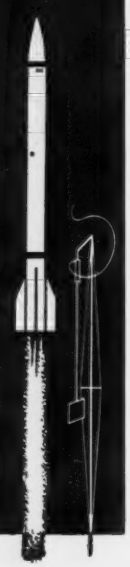


GMA–Solenoid or Manual Release. 41 to 140 Contacts. Coaxials Available.

GMJ–Skid Away Release. 18 Size 14 Contacts.

GMD–Skid Away Release. 22 or 50 Size 14 Contacts.

Performance of missile launching connectors cannot be "hit or miss." It must be right! That's where Cannon's reputation for quality and design experience can help you with the most complete and most reliable line available.



Write TODAY for GM1 Bulletin

CANNON PLUGS

CANNON ELECTRIC CO.
3209 Humboldt Street
Los Angeles 31, Calif.

Please Refer to Dept. No. 185

Tagung, Göttingen, Oct. 7, 1955.) *ZAMM*, Sonderheft, Aug., 1956, p. 25. In German. Study of the pressure loss in pipes of noncircular cross section at high velocities.

Transmission of Oscillatory Pressures Through Instrument Pipe Lines. Shin'ichiro Takeda. *Hosei U. Tech. Coll. Rep. 1*, May, 1956. 37 pp. Theoretical and experimental investigation of a compressible fluid in a pipe line.

On the Effects of the Reynolds Stress on Hydrodynamic Stability. J. T. Stuart. (*GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.*) *ZAMM*, Sonderheft, Aug., 1956, pp. 32–38. Investigation of the theory of hydrodynamic instability for finite disturbances.

Gas Flow and Units; A Method of Simplifying Gas Flow Equations. V. D. Naylor. *Aircraft Eng.*, Aug., 1956, p. 279. Description of an analytic method using the reservoir conditions as the unitary system to simplify visually the resulting equations.

Einfluss der Oberflächenspannung auf die Ausbildung von Flüssigkeits-Hohlstrahlen. G. A. Euteneuer. *Forschung Gebiete Ing., Ausg. A*, No. 4, 1956, pp. 109–122. In German. Study of the influence of surface tension on the development of hollow liquid jets indicating that the development of such jets, produced by means of annular spray nozzles, can be calculated under the assumption of frictionless flow. Jet borders are evaluated from the established theory for various values of surface tension and density of the liquid, of the initial jet velocity, and of the design data of the spray nozzle, and are found to be in good agreement with observed jet borders up to the point where the jet breaks up into droplets.

Über die Grenzschicht an der Wand eines Trichters mit innerer Wirbel und Radialströmung. K. Gargsch. (*GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.*) *ZAMM*, Sonderheft, Aug., 1956, pp. 11–17. In German. Study of the boundary layer along the wall of a funnel with internal vortex and radial flow, taking into account the Pohlhausen theory.

Stability & Control

High Altitudes Increase Airplane Stability Problems. E. R. Heald. *SAE J.*, Aug., 1956, pp. 25–27. Abridged. Discussion of the effects of high Mach Number, high angle of attack, and the resulting reduction of lift-curve slope on the stability of high-altitude aircraft.

Stability and Control Problems Associated with Supersonic Aircraft. I. O. E. Michaelsen. *Canada, NAE Quart. Bul.*, Apr. 1–June 30, 1956, pp. 1–17. Analysis of the problem including static stability and trim, longitudinal dynamic stability and trim, directional stability, and dihedral effect and lateral control.

Die Bestimmung der Flugzeugpolaren für Entwurfszwecke. I—Unterlagen. D. Fiecke. *DVL Bericht No. 15*, June, 1956. 242 pp. 352 refs. Westdeutscher Verlag, Köln & Opladen. In German. Compilation of diagrams used for the determination of polars for different flight attitudes.

Wings & Airfoils

A Method for Optimizing Two-Dimensional Airfoils. Thomas A. Cincotta. *Princeton U. Dept. Aero. Eng. Rep. 355*, May, 1956. 31 pp. Description of a procedure involving comparison of the viscous and nonviscous solution and application of boundary-layer control in such a way that the ideal nonviscous solution is approached.

Some Recent Developments in the Aerodynamics of Wings for High Speeds. Robert T. Jones. *ZFW*, Aug., 1956, pp. 257–262. 32 refs.

Un Método para Determinar Características de Perfiles Alares. Leonardo D'Attorre. (*Rev. Fac. Cienc. Fisicomat.*, Jan., 1956, pp. 17–43.) *La Plata, U. Nac. Fac. Cienc. Fisicomat. Dept. Aero., Pub. 57*, 1956. 26 pp. 11 refs. In Spanish. Method giving a numerical approximate solution to the problem of airfoil characteristics using a Germain's operator, and applicable to both symmetrical and antisymmetrical airfoils.

Theoretical and Experimental Investigation of the Subsonic-Flow Fields Beneath Swept and Unswept Wings with Tables of Vortex-Induced Velocities. Appendix A—**Detailed Theoretical Considerations.** Appendix B—**Downwash, Sidewash, and Backwash Functions Due to a Unit Horseshoe Vortex.** William J. Alford, Jr. *U.S., NACA TN 3738*, Aug., 1956. 91 pp. 24 refs.

Ergebnisse einer Näherungstheorie für die schallnahe Strömung um verwundene und gewölbte dünne Flügel. Friedrich Keune. *ZFW*, Aug., 1956, pp. 276–280. In German. Presentation of numerical results for pressure distribution, lift, moment, and zero-lift incidence for some twisted and cambered pointed wings with series of local span distributions.

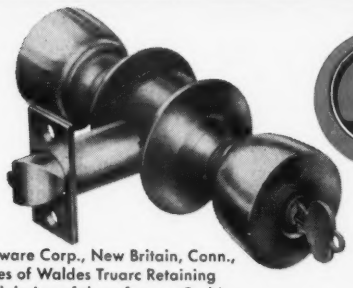
On Transonic Airfoil Theory. Gottfried Guderley. *J. Aero. Sci.*, Oct., 1956, pp. 961–969. Theoretical investigation of the development of flow over an airfoil with respect to the reciprocal of the aspect ratio, taking into account the effect of the flow field at a distance from the profile on that close to the profile.

Auftriebslöschung und Aufwindlöschung, zwei duale Methoden der linearisierten Überschalltragflächentheorie; Anwendung auf den Doppeldreiecksflügel. Hermann Behrbohm. *ZFW*, Aug., 1956, pp. 263–268. In German. Development of an upwash cancellation technique which is applied to the calculation of total lift and pitching moment for thin double delta wings in supersonic flow.

Über den Auftrieb eines Ringflügels bei beschleunigtem oder verzögertem Überschallflug. Jürgen Zierep. *ZFW*, Aug., 1956, pp. 269–272. In German. Method of characteristics is given for estimating the lift of a body with a stabilizing annular ring at any instant of accelerated or decelerated flight.

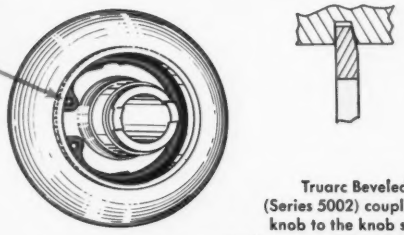
Some Preliminary Results from Wind Tunnel Measurements on Models with Annular Wings at Supersonic Speeds. Lars-Erik Nordström. *ZFW*, Aug., 1956, pp. 272–276. Investigation performed at Mach Numbers 2 and 3 on annular wings, concentrically mounted on cone-cylindrical bodies of revolution.

Waldes Truarc Retaining Rings Eliminate Machining—Provide Stronger Assembly, Greater Accuracy



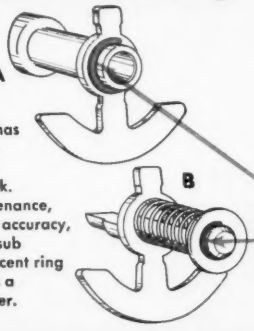
The American Hardware Corp., New Britain, Conn., uses 4 different types of Waldes Truarc Retaining Rings in the original design of these famous Corbin and Russwin Heavy Duty Cylindrical Locks. Truarc rings improve product performance, eliminate rejects, and cut labor costs.

Knob Sub Assembly



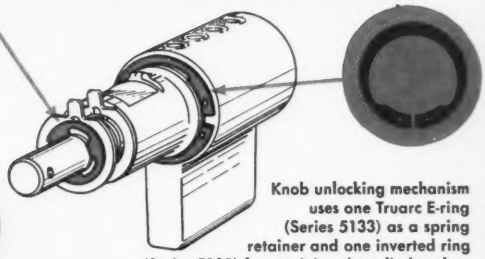
Truarc Beveled Ring (Series 5002) couples the knob to the knob shank. It eliminates two tapped holes and two screws, provides stronger assembly and greater accuracy. Beveled ring takes up end play rigidly.

Spindle Sub Assembly



Spindle sub assembly "A" has two Waldes Truarc crescent rings (Series 5103) used as locating flanges for rollback. This saves labor and maintenance, improves performance and accuracy, eliminates rejects. Spindle sub assembly "B" uses one crescent ring as a spring retainer and as a locating shoulder for washer.

Cylinder Sub Assembly



Knob unlocking mechanism uses one Truarc E-ring (Series 5133) as a spring retainer and one inverted ring (Series 5108) for retaining the cylinder plug. Rings are re-usable in the event of disassembly for maintenance. Rejects are eliminated.

Whatever you make, there's a Waldes Truarc Retaining Ring designed to improve your product...to save you material, machining and labor costs. They're quick and easy to assemble and disassemble, and they do a better job of holding parts together. Truarc rings are precision engineered and precision made, quality controlled from raw material to finished ring.

36 functionally different types...as many as 97 different sizes within a type...5 metal specifications and 14 different finishes. Truarc rings are available from 90 stocking points throughout the U.S.A. and Canada.

More than 30 engineering-minded factory representatives and 700 field men are available to you on call. Send us your blueprints today...let our Truarc engineers help you solve design, assembly and production problems...without obligation.

For precision internal grooving and undercutting...Waldes Truarc Grooving Tool!

Send for new catalog supplement

WALDES TRUARC® RETAINING RINGS

Waldes Kohinoor, Inc., 47-16 Austel Place, L. I. C. 1, N. Y.
Please send the new supplement No. 1 which brings Truarc Catalog RR 9-52 up to date.
(Please print)

Name.....
Title.....
Company.....
Business Address.....
City.....Zone.....State.....
AE118

DEPARTMENT OF TECHNOLOGY BUFFALO AND ERIE COUNTY PUBLIC LIBRARY

WALDES TRUARC Retaining Rings, Grooving Tools, Pliers, Applicators and Dispensers are protected by one or more of the following U. S. Patents: 2,382,948; 2,411,426; 2,411,761; 2,416,852; 2,420,921; 2,428,341; 2,439,785; 2,441,846; 2,455,165; 2,483,379; 2,483,380; 2,483,383; 2,487,802; 2,487,803; 2,491,306; 2,491,310; 2,509,081; 2,544,631; 2,546,616; 2,547,263; 2,558,704; 2,574,034; 2,577,319; 2,595,787, and other U. S. Patents pending. Equal patent protection established in foreign countries.

Mars Pencils Sponsors Tomorrow's Designs

MARS OUTSTANDING DESIGN SERIES—featured in the current advertising of J. S. Staedtler, Inc.—has attracted widespread attention among the users of fine drafting pencils. It has fulfilled our expectation that the men who appreciate the finest working tools are those with a lively creative interest in new designs, new projects, new ideas.

Concerned with unusual projects—*designs of the future*—Mars Outstanding Design Series provides a "showcase" for originality, for interesting work of engineers, architects, and students which so often lies buried. To stimulate you to send in *your* designs, Mars Pencils

will pay you $100

for any design accepted. This $100 is paid you simply for the right to reproduce your project in the Mars Outstanding Design Series. There are no strings attached. You will be given full credit. (See ad on facing page—one of the ads in the current series.) All future rights to the design remain with you. You can reproduce it later wherever you like and sell or dispose of it as you wish.

The subject can be almost anything—aviation, space travel, autos, trains, buildings, engineering structures, household items, tools, machines, business equipment, etc. It should be a project that appeals to design-minded readers, be of broad interest, and be attractively presented. Do not submit a design that has been executed. As a matter of fact, the project does not need to have been planned for actual execution. It should, however, be something that is either feasible at present or a logical extension of current trends. It cannot be unrealistic or involve purely hypothetical alterations of natural laws.

There is no deadline for entries but the sooner you send yours in, the greater the probability of its use as one of the subjects in the 1957 Mars Outstanding Design Series.

It Is Simple To Submit a Design For Mars Outstanding Design Series

Just mail in an inexpensive photostat or photocopy of the subject—one you can spare, since it cannot be returned.

If your entry is accepted, we will ask you to send in a sharp photograph of the design, or the design itself, so that we can make a sharp photograph suitable for reproduction—after which it will be returned to you promptly.

Send your entry to:

J.S. STAEDTLER, INC.
DICAROUS COURT, HACKENSACK, NEW JERSEY

Note on the Wave Drags of Untapered Wings with Streamwise Tips at Zero Lift. A. D. Young. *Aero. Quart.*, Aug., 1956, pp. 240–246. Calculation based on linearized supersonic-flow theory demonstrating the equivalence between the wave drags of yawed or swept wings of constant section and zero lift and corresponding values in two-dimensional flow.

A Study of Optimum Spatial Lift Distributions at Supersonic Speeds. A. M. Rodríguez. *Douglas Rep. SM-19292*, Nov., 1955. 39 pp. Generalization of the previously obtained approach applied to the problems of spatial lift distribution and interference.

O Soprotivlenii, Sviazannom s Sozdaniem Pod'emnoi Sily pri Sverkhzvukovoi Skorosti Potoka. G. I. Taganov. *Prikl. Mat. i Mekh.*, May-June, 1956, pp. 382–394. In Russian. Study of drag related to the generation of lift at supersonic speeds, based on Prandtl results, and emphasizing the Munk condition.

Matrices, para el Cálculo de la Distribución Simétrica de la Sustentación por el Método de Pasqualini. R. Rabadan and C. Gentile. (*Rev. Fac. Cienc. Fisicomat.*, Jan., 1956, pp. 44–57.) *La Plata, U. Nac. Fac. Cienc. Fisicomat. Dept. Aero., Pub. 58*, 1956. 14 pp. In Spanish. Method employing matrices for practical calculation of the lift distribution for wings of finite span by Pasqualini's method.

Distribución de la Sustentación con Diagrama no Lineal. Clodoveo Pasqualini. (*Rev. Fac. Cienc. Fisicomat.*, vol. I, pp. 137–151.) *La Plata, U. Nac. Fac. Cienc. Fisicomat. Dept. Aero., Pub. 54*, 1954. 15 pp. In Spanish. Method based on Germain's operators for calculating the lift along the span of a finite wing for the case when the lift of a profile section is not a linear function of incidence.

Note on the Forces that Act near the Centre and the Tips of Swept Wings. Appendix I—**The Flow at Large Distances from a Semi-Infinite Yawed Wing.** D. G. Hurley. *Australia, ARL AN 150*, Feb., 1956. 14 pp. Development of a simple exact method for calculating the force acting near the end of a semi-infinite yawed wing of symmetrical section at zero.

A Theory of Slender Delta Wings with Leading Edge Separation. K. W. Mangler and J. H. B. Smith. *Gt. Brit., RAE TN Aero. 2442*, Apr., 1956. 21 pp. 14 refs. Development of a potential theory for the "core," a region of flow with high vorticity produced by the rolling-up of the vortex sheet which extends from the wing and is formed by the separation of flow at incidence, along the highly swept leading edge of a slender delta wing. The theory assumes a conical velocity and is further based on the assumptions of slender-wing theory.

Aeroelasticity

Fatigue Summed Up. *Aeronautics*, Aug., 1956, pp. 38, 39. Abridged. Discussion of factors affecting fatigue properties, including type of stress, surface treatment and finish, corrosion, stress raisers, and gust loading effects.

The Vibration of Segmented Beams. J. P. Ellington. *Brit. J. Appl. Phys.*, Aug., 1956, pp. 299–303. Theoretical investigation to obtain the frequency equations and normal modes for the flexural oscillations of a light beam carrying equal and equally-spaced concentrated masses. Includes discussion of the mass distribution in the "lumped mass" approximation to a continuous beam.

Vibration of Isosceles Triangular Plates Having the Base Clamped and Other Edges Simply-Supported. Hugh L. Cox and Bertram Klein. *Aero. Quart.*, Aug., 1956, pp. 221–224. Derivation of approximate solutions for the lowest natural frequency of flexural vibration of isosceles triangular plates.

Ob Ustoichivosti Neustanovivshikhsia Dvizhenii. B. S. Razumikhin. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1956, pp. 266–270. In Russian. Study of the stability of unsteady motions, taking into account Chetaev's results.

O Nekotorykh Zadachakh ob Ustoichivosti Dvizheniia v Mekhanike. N. G. Chetaev. *Prikl. Mat. i Mekh.*, May-June, 1956, pp. 309–314. In Russian. Analysis of the Liapunov formulation of the problem of stability of motion, based on Lagrange independent determinant coordinates.

O Kolebanii Plastinki, Dvizhushcheisia v Gaze. A. A. Movchan. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1956, pp. 211–222. In Russian. Investigation of oscillations of a plate of infinite width moving through a gas at supersonic speeds in the direction from the fixed edge toward the free edge.

Obrashchenie Teorem Vtorogo Metoda Liapunova i Voprosy Ustoichivosti Dvizheniia po Pervomu Priblizheniiu. N. N. Krasovskii. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1956, pp. 255–265. 22 refs. In Russian. The theorems of the Liapunov second method and the problems of stability of motion are transformed according to the first approximation.

Sobre el Cálculo de las Frecuencias Propias y Formas de Oscilación. Plácido Cicala. (*Rev. Fac. Cienc. Fisicomat.*, Jan., 1956, pp. 3–16.) *La Plata, U. Nac. Fac. Cienc. Fisicomat. Dept. Aero., Pub. 56*, 1956. 14 pp. In Spanish. Analysis of the transition error in the determination of successive harmonics of an elastic vibration system giving a method for obtaining the amplitude of the higher frequency harmonics.

Interim Note on Counting Accelerometer Results Obtained from Viscount Aircraft. N. E. Bacon. *Australia; ARL S&M Note 227*, May, 1956. 13 pp. Detailed analysis of the results of 125 hours of photographic recording as part of a program to determine gust loads on a Viscount aircraft operating between the five state capital cities of the Australian mainland. Results indicate a marked bias toward downward gusts noted on all routes.

The Dynamic Response of a Large Airplane to Continuous Random Atmospheric Disturbances. Appendix A—**Derivation of the Input-Output Relation and Various Transfer Functions for a One-Dimensional Gust Structure.** Appendix B—**Derivation of Output of Spectra for a Two-Dimensional Gust Structure.** Franklin W. Diederich. (*IAS 23rd Annual Meeting, New York, Jan. 24–27, 1955, Preprint 548.*) *J. Aero. Sci.*, Oct., 1956, pp. 917–930. 18

refs. Analysis of gust loads using a statistical approach and taking into account the effect of lateral variations of the instantaneous gust intensity on the aerodynamic forces and on the resultant motions and stresses of rigid and flexible airplanes.

Aeronautics, General

A Digest of Summer Meeting Papers. (*IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956.*) *Aero. Eng. Rev.*, Oct., 1956, pp. 76–81. Contents: Aerodynamic Heating (Aerodynamic Aspects). Aerodynamic Heating (Structural Aspects). Operation of Large Turbine-Powered Aircraft. Low-Speed Flight. Economics. Sociological Influences of Aviation. Advanced Techniques. Discussion of 17 technical papers (excluding confidential sessions) covering aerothermodynamics, thermal stresses, jet operational experience of the Strategic Air Command, recent development in STOL and VTOL aircraft, economics of the aircraft industry, the rate of growth of air transportation, and progress in nuclear power plants and suitable shielding.

Special Issue: Commonwealth Aircraft Industries. *Flight*, Aug. 24, 1956. 124 pp. Extensive documentary coverage including types and design of aircraft, progress in research, and a directory to commonwealth aircraft manufacturers.

La Ricerca Aeronautica e i suoi Riflessi sul Progresso dell'Aviazione Civile. Luigi Broglio. *Cen. Sviluppo Transp. Aerei (Rome), Conf. Rep.* 48, Jan. 20, 1956. 22 pp. In Italian. General survey of development in the field of aeronautics and of problems encountered, including the sound and thermal barriers, rocket propulsion, and speed considerations.

Gestaltung der Lehrtätigkeit in der Luftfahrttechnik in Grossbritannien. A. D. Young. *Nordrhein-Westfalen, Arbeitsgemeinschaft für Forschung, Heft 52*, 1956, pp. 35–62; Discussion, pp. 63–82. In German. Discussion of education and training activities in the field of aeronautics in Great Britain.

Der Air Registration Board und seine Aufgaben im Dienst der britischen Flugzeugindustrie. F. W. A. Patmore. *Nordrhein-Westfalen, Arbeitsgemeinschaft für Forschung, Heft 52*, 1956, pp. 7–22; Discussion, pp. 23–33. In German. Review of activities of the Air Registration Board and its role in the British aircraft industry.

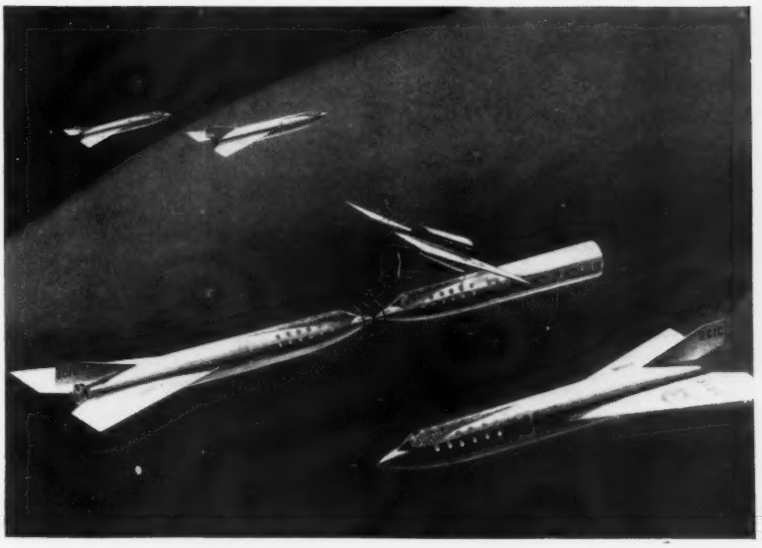
Airplane Design

Designing for Aircraft Safety. M. Carl Haddon. *Interavia*, July, 1956, pp. 519–521. Discussion of Lockheed Electra design features which contribute to safety through performance, reliability, and controllability.

The Vickers Vanguard. James Hay Stevens. *Aircraft (Canada)*, Aug., 1956, pp. 24–28, 76, 77, cutaway drawing. Design, structural, and performance characteristics of British turboprop air liner.

Capital's Choice—The Comet 4A. *The Aeroplane*, July 27, 1956, pp. 125–128. Description of an adaptation of the Comet 4 for obtaining its normal operating limit,

MARS outstanding design SERIES



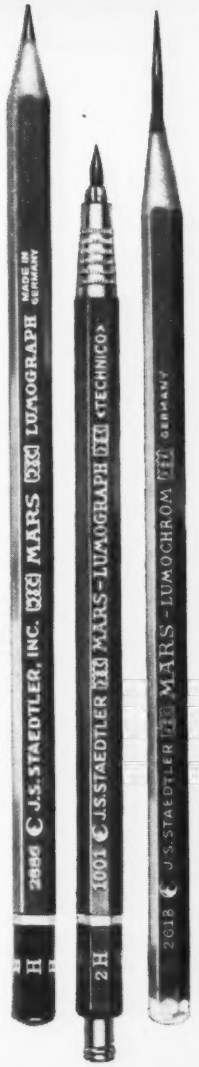
birth of a satellite

Most new ideas, like this inhabited satellite, start out as drawings on a sheet of paper. Here artist Russell Lehmann shows the first step in building the space station proposed by Darrell C. Romick, aerophysics engineer at Goodyear Aircraft.

Two ferry ships, one stripped of rocket units, are joined end to end. As others are added, this long tube forms temporary living quarters for crews. Eventually, outer shell will be built around core, making completed station 3,000 feet long, 1,500 feet in diameter.

No one can be sure which of today's bright ideas will become reality tomorrow. But it is certain that in the future, as today, it will be important to use the best of tools when pencil and paper translate a dream into a project. And then, as now, there will be no finer tool than Mars — from sketch to working drawing.

Mars has long been the standard of professionals. To the famous line of Mars-Technico push-button holders and leads, Mars-Lumograph pencils, and Tradition-Aquarell painting pencils, have recently been added these new products: the Mars Pocket-Technico for field use; the efficient Mars lead sharpener and "Draftsman's" Pencil Sharpener with the adjustable point-length feature; and — last but not least — the Mars-Lumochrom, the new colored *drafting* pencil which offers revolutionary drafting advantages. The fact that it blueprints perfectly is just one of its many important features.



The 2886 Mars-Lumograph drawing pencil, 19 degrees, EXEXB to 9H. The 1001 Mars-Technico push-button lead holder. 1904 Mars-Lumograph imported leads, 18 degrees, EXB to 9H. Mars-Lumochrom colored *drafting* pencil, 24 colors.

J.S. STAEDTLER, INC.
HACKENSACK, NEW JERSEY

at all good engineering and drawing material suppliers

Mach Number 0.74, at any altitude upwards of 20,000 ft.

Red Round-Up; A Synthesis of the Post-War Development of Russian Aircraft Design. *Flight*, Aug. 3, 1956, pp. 185–188. Discussion of design and performance characteristics of Russian aircraft displayed at 1956 Red Air Day. Includes three-view drawings of twelve types of aircraft.

Tailor Made for Air Trading. D. M. Desoutter. *Aeronautics*, Aug., 1956, pp. 44–57. Design, performance, and structural characteristics of the Handley Page Herald, including description of systems and specific operational data for South American and African air lines.

High-Speed Problems of Large Airplanes. George S. Schairer. (*ASME Av. Conf., Los Angeles, Mar. 14–16, 1956, Paper 56–AV-24.*) *Mech. Eng.*, Sept., 1956, pp. 832–836.

Aircraft Control Systems; A Review from the Pilot's Angle. A. Spooner and L. F. E. Coombs. *Flight*, Aug. 17, 1956, pp. 256–260. Discussion of several different types of control systems and their application to particular aircraft types.

Air Conditioning & Pressurization

Condiționarea Aerului la Bordul Avioanelor. C. Dimitrie Trăușanu. *Rev. Transp.*, Jan., 1956, pp. 23–27. In Rumanian. Air conditioning and pressurization of aircraft.

Cockpits

Design Details and Rubber Compounds for Large-Area Low-Pressure Closure Seals. Russell W. Beckim. *Mach. Des.*, Sept. 6, 1956, pp. 97–100. Discussion of types and applications of closure seals and types of rubber compounds to be used in their construction.

Landing Gear

The Theory and Prevention of Undamped Aeroplane Nosewheel Shimmy. D. Williams. *Aero. Quart.*, Aug., 1956, pp. 193–220. Development of a mathematical theory of nosewheel shimmy, with particular emphasis on twin nosewheel assemblies. Experimental verification of the theory is outlined.

Méthode de Calcul des Amortisseurs Oléopneumatiques et Comparaison Avec les Résultats d'Essais Obtenus. E. Bazzocchi. *Tech. et Sci. Aéronautiques*, No. 3, 1956, pp. 125–139. In French. Development of a method for calculating oleo-pneumatic shock absorbers in aircraft landing gear.

Tests to Determine the Adhesive Power of Passenger-Car Tires. B. Förster. *U.S., NACA TM 1416*, Aug., 1956. 36 pp. Investigation to determine tractive, braking, and track adhesion of tires. Methods are applicable to similar tests for larger aircraft tires.

Operation & Performance

Economics of Rocket-Propelled Airplanes. II. Appendix I—**Fuels Costs.** Appendix II—**Cost of Placing Material in a Satellite Orbit.** Appendix III—**Properties of Nuclear-Powered Rocket Airplanes.** Robert Cornog. *Aero. Eng. Rev.*, Oct., 1956, pp. 49–58. Discussion of depreciation costs, maintenance, labor costs, and freight and passenger fares.

Airports

Special Issue: Carburants et Lubrifiants 1956. *Vitesse Speed*, No. 4, 1956. 32 pp. In French and English. Contents: Le Ravitaillement des Avions en Carburant d'Hier à Aujourd'hui, André Charriou. Le Matériel de Ravitaillement en Combustible sur les Aéroports, M. Michaud. Le Ravitaillement des Avions en Carburant, J. Quenette. Le Développement des Lubrifiants Synthétiques pour Turbines à Gaz d'Avions, D. W. Bedell. Le Remplissage sous Pression des Réservoirs d'Avions, Richard Nouare. General survey of refueling problems, development of synthetic lubricants for gas turbines, and ground equipment used.

Aviation Medicine

Human Engineering

The Role of Visual Cues in Final Approach to Landing. II—A Proposed Airborne Approach Aid. III—Proposed Research Programme on Visual Cues and Approach Aids. Appendix I, II—**Modified Navy Angle of Approach Indicator.** Appendix III—**A Training Device for Simulating Visual Landings or Visual Landings Following Instrument Approaches.** Appendix IV—**Feasibility of Constructing a Universal Airborne Approach Sight.** J. C. Lane and R. W. Cumming. *Australia, ARL Note HE. 1*, May, 1956. 48 pp. 22 refs.

Computers

Information Theory. Martin L. Klein, Frank K. Williams, and Harry C. Morgan. *Instruments & Automation*, Aug., 1956, pp. 1,519–1,524. Description of a means for comparing analog and digital systems and for designing digital systems to have an accuracy equivalent to a given analog system.

A Discussion of Precision Computer Transformers. D. Wildfeuer. *Tele-Tech*, Sept., 1956, pp. 70–72, 127 ff. Analysis based on the nonexistence of transients and on the presence of humped impedances for conventional isolated winding and auto-transformers. Methods for manipulating various elements of a transformer in order to influence out-of-phase and in-phase error are shown.

Analogue vs Digital Techniques for Engineering Design Problems. D. B. Breedon. *Elec. Eng.*, Sept., 1956, pp. 814–816. Description of computer characteristics and presentation of examples of the type of problems which analog and digital computers are being called upon to solve.

Principles and Design Uses for Analog Simulators. II—How to Use the Simulator in Vibration Analysis. J. N. Macduff. *Mach. Des.*, Sept. 6, 1956, pp. 106–113. 16 refs. Solutions of differential equations representing the motion of a damped vibrating body using two methods—the mathematical and the direct simulation methods.

Applications of a Transformer Analogue Computer. J. R. Barker. *Brit. J. Appl. Phys.*, Aug., 1956, pp. 303–307. Discussion showing that the Blackburn analyzer can be used to solve many algebraic problems involving real or complex numbers, including the extraction of the latent roots of matrices, the location of the zeros of polynomials, and the solution of linear and nonlinear simultaneous equations.

A General Purpose Electronic Analogue Computor. III. R. J. A. Paul. *Proc. Inst. Electronics*, Fourth Quarter, 1955, pp. 25–35. 34 refs.

Education & Training

Evaluation of Training Devices for B-47 Fuel, Hydraulic, and Rudder Power Control Systems. Robert A. Swanson and Lewis E. Aukes. *USAF PTRC TN 56-2*, Jan., 1956. 43 pp. 29 refs. Devices investigated include animated panels, cutaway trainers, operating and non-operating trainers, charts, and symbolic diagrams.

Factors Influencing Attitude Change Through Refutative Communications. Donald L. Thistlethwaite, Joseph Kamenetsky, and Hans Schmidt. *USAF PTRC TN 56-64*, June, 1956. 25 pp. USAF-supported experimental investigation of various methods of presenting arguments to an audience with opposed beliefs, in order to determine which approach is most successful in terms of arousing the least antagonism, getting the ideas across, and effecting a change in attitude.

Relationships Between Attitudes of Bomber Crews in Training and Their Attitudes and Performance in Combat. Dorothy M. Knoell. *USAF PTRC TN 56-49*, Apr., 1956. 44 pp.

Safety and Economic Aspects of Flight Simultators. A. F. Bonnalie. (*IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Paper.*) *Aero. Eng. Rev.*, Oct., 1956, pp. 71–75. Evaluation of simulator advantages and limitations for flight training, and consideration of the parameters to be taken into account in the selection of a particular simulator.

Electronics

Predicting the Reliability of Airborne Equipment. C. J. Hedetniemi. *Tele-Tech*, Sept., 1956, pp. 62–64, 114 ff. Analysis of available data on seven types of military and commercial electronic equipment, and evaluation of measures for eliminating the problem of malfunction, including periodic overhaul and maintenance programs.

Reliable Soldered Connections Without Mechanical Joints. J. Roy Smith. *Elec. Mfg.*, Sept., 1956, pp. 143–145. Description of simplified procedures for wrapping connections before the soldering operation.

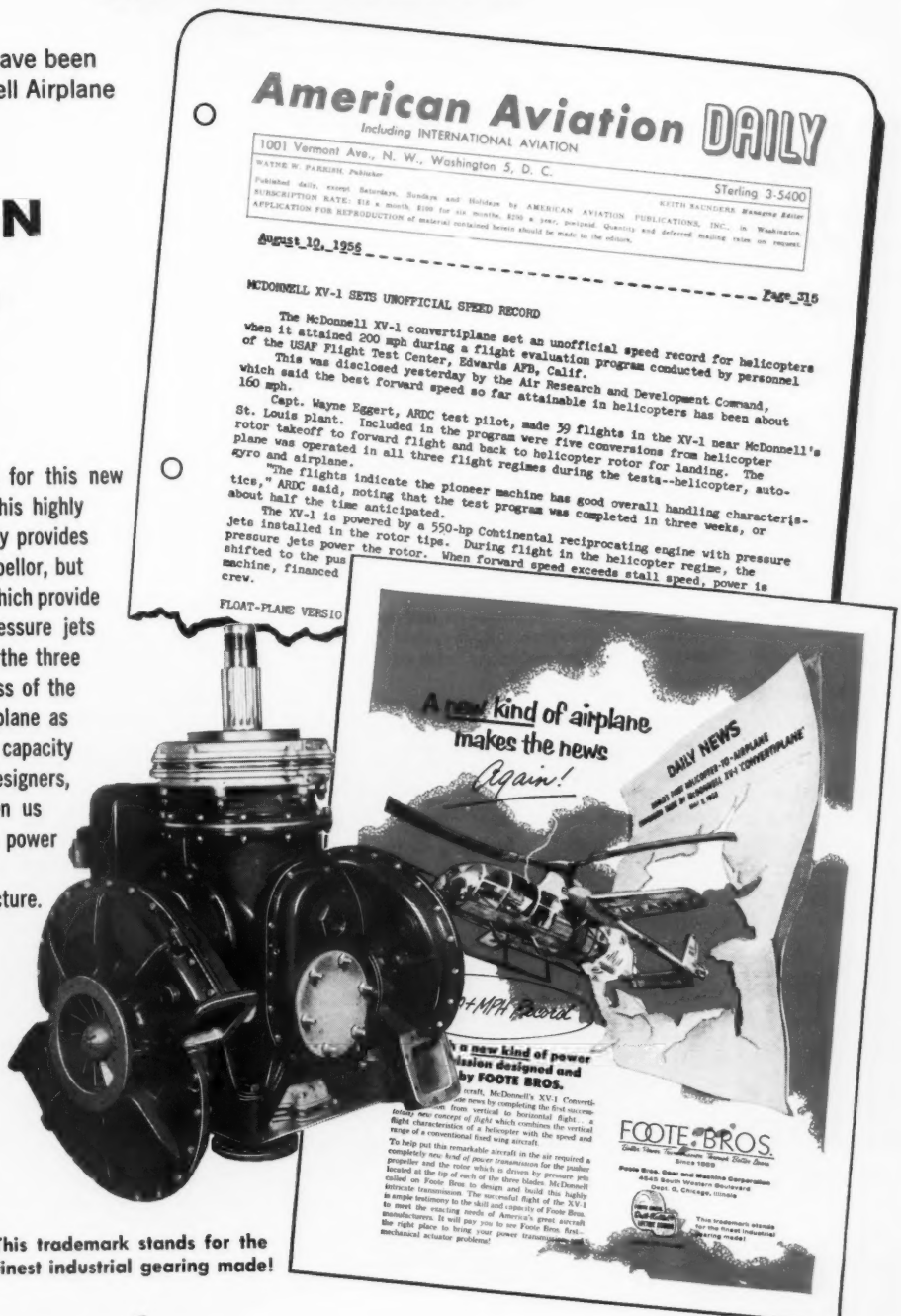
Forced-Air Techniques for Cooling Electronic Equipment. Melvin Mark and Mark Stephenson. *Elec. Mfg.*, Sept., 1956, pp. 130–136, 372 ff. 15 refs. Analysis of the cooling problem for air-borne electronic equipment considering the vacuum tube as the basic heat-generating source.

XV-1 Convertiplane is AGAIN in the news

Foote Bros. is proud to have been selected by the McDonnell Airplane Corporation to...

- **DESIGN**
- **BUILD**
- **TEST**

the power transmission unit for this new concept in aircraft design. This highly intricate transmission not only provides the power for the pusher propellor, but also drives the compressors which provide air for the rotor through pressure jets located in the tip of each of the three blades. We regard the success of the transmission in the Convertiplane as a testimonial to the skill and capacity of the Foote Bros. team of designers, builders, and testers. Call on us when you have a problem in power transmission or mechanical actuator design and manufacture.


American Aviation DAILY
Including INTERNATIONAL AVIATION
1001 Vermont Ave., N. W., Washington 5, D. C.
August 10, 1956
MCDONNELL XV-1 SETS UNOFFICIAL SPEED RECORD
A new kind of airplane makes the news Again!
DAILY NEWS
FOOTE BROS.

FOOTE BROS. Dual-Rated® LIFETIME GEARING

T.M. REG. U.S. PAT. OFF.

This trademark stands for the finest industrial gearing made!

FOOTE BROS.

Better Power Transmission Through Better Gears

Since 1859

FOOTE BROS. GEAR and MACHINE CORPORATION
4545 South Western Boulevard
Dept. G, Chicago, Illinois

FLEXONICS

... First in ducting and flexible assemblies for the Aircraft Industry

FIRST Flexible, stainless steel hose.

FIRST Flexible, stainless steel bellows.

FIRST Flexible, multi-ply stainless steel bellows.

FIRST Hi-strength, butt welded, thin wall stainless steel ducting.

FIRST Formed, thin wall, butt welded, high strength, stainless steel duct components.

FIRST Metal foil, sheathed and sealed, insulated ducting, non wicking.

FIRST Complete design, manufacture and qualification of an entire high temperature aircraft duct system: Heat and vent, refrigeration, anti-icing and boundary layer control.

FIRST Supplier to install pneumatic duct flow facilities for environmental testing of components and complete duct systems.

At Flexonics Corporation, forward thinking engineers produce ducting, hose, connectors and bellows that can help you put a plane in the air that will fly farther . . . faster . . . more safely . . . more comfortably.

It is our goal to do more than just fabricate components that "meet the requirements." It is our goal to contribute to the advancement of aircraft engineering by developing new and better means of doing the job. In less than twenty years, this philosophy has led to many significant Flexonics firsts, as the list above shows.

The imagination, engineering skill and fabricating know-how that created these firsts can be made a part of your organization. The first step is to send an outline of your problem. Do it, today!

Ask how you can get a copy of the Flexonics Aircraft Engineering Manual.

FLEXON® QUALITY proved in service and backed by over 54 years manufacturing experience

RFA-30

Flexonics Corporation
AIRCRAFT DIVISION
1309 S. THIRD AVENUE, MAYWOOD, ILLINOIS
FORMERLY CHICAGO METAL HOSE CORPORATION

Manufacturers of flexible metal hose and conduit, expansion joints, metallic bellows and assemblies of these components.
In Canada: Flexonics Corporation of Canada, Ltd., Brampton, Ontario

The Study of Thermal Conductivity Problems by Means of the Electrolytic Tank. F. Reiniger. *Philips Tech. Rev.*, July 27, 1956, pp. 52–60. Description of an investigation into the thermal behavior of an oil-cooled copper X-ray anode with a small thin plate of tungsten embedded in it.

Disc-Seal Triode Amplifiers. G. Craven. *Wireless Engr.*, Aug., 1956, pp. 179–183. Analysis of the design of a resonant π-type coupling network for disc-seal triodes operating in the earthed-grid connection at frequencies in the 300–3,000 Mc/s range.

Matrix Theory of Skin Effect in Laminations. Louis A. Pipes. *J. Franklin Inst.*, Aug., 1956, pp. 127–138. Description of a mathematical technique, based on the fundamental Maxwell field equations, for determining the magnetic and electric field intensities and the current density in plane conducting metal plates of constant permeability produced by an external impressed alternating magnetic field.

A Less-Than-Minimum Phase Shift Network. R. F. Destebelle, C. J. Savant, and C. J. Savant, Jr. *Tele-Tech*, Sept., 1956, pp. 60, 61, 106. Description of a circuit which consists of a combination of a tuned amplifier and a phase-sensitive demodulator which obviates instabilities, thus permitting the use of high Q amplifiers.

Bandwidth and Noise Sensitivity. D. S. Radmacher. *Tele-Tech*, Sept., 1956, pp. 74, 75, 121, 122. Discussion of methods for establishing effective noise-free bandwidths.

One Knob Tunes Klystron Oscillator. Jerome Altman and Kingsley Craft. *Electronics*, Sept., 1956, pp. 186–189. Description of an instrument which may be used as a basic unit in a tunable mti radar system and whose automatic control is provided by a dual-mode reference cavity and differential amplifiers combined in feedback loops.

Motor Drives for W-Series Variacs. *Gen. Radio Exp.*, Aug., 1956, pp. 1–4. Description of mechanical design, types of motors, and enclosures, with specifications and price list.

Film Resistors of Nitride Compounds. E. H. Layer and E. R. Olson. *Elec. Mfg.*, Sept., 1956, pp. 104–109, 310 ff. Development of film resistors formed by nitriding and conditioning an evaporated chromium film. These resistors have a high stability, low temperature coefficient of resistance, and high resistance values.

Application of Sequence Transform Analysis to the Design of Sampling Control Systems. A. R. Boothroyd and J. H. Westcott. *Gt. Brit., RAE TN GW 405*, Mar., 1956. 53 pp. Analysis of sampling control systems in which the input is in the form of discrete samples rather than continuous ones. The techniques described are applicable to guided-weapon systems in which the guidance information is obtained intermittently.

Excitation and Separation of Pure High-Order Modes in Large High-Q Cavities. C. T. Zahn and W. G. Schweitzer, Jr. *J. Appl. Phys.*, Aug., 1956, pp. 929–937. ARDC-supported derivation of a new design principle for cavity-coupling systems, based on a detailed study of the theoretical field patterns in various types of cavity

mode, taking into account the axially symmetric transverse electrical modes of a cylindrical cavity.

Back-Scatter Ionospheric Sounder; Single-Station Equipment for Oblique Incidence Propagation Studies. E. D. R. Shearman and L. T. J. Martin. *Wireless Engr.*, Aug., 1956, pp. 190–201. 10 refs.

Amplifiers

Magnetic-Amplifier Control of Switching Transistors. H. W. Collins. *Elec. Eng.*, Sept., 1956, p. 812. Discussion of a circuit which uses a variable-width output pulse of an audio-frequency magnetic amplifier as a means for linearly controlling the output of switching transistors.

Nonlinear Amplifier Design for Pulse-Height Analyzers. G. W. Hutchinson. *Rev. Sci. Instr.*, Aug., 1956, pp. 592–596. Description of an apparatus which provides a discriminator and gate circuit and which is based on the principle that the ratio of maximum to minimum pulse sizes (which can be recorded simultaneously by a kick sorter) is limited by the curvature of the characteristic of its biased amplifier over a finite region of input potentials; the extent of this region can be reduced from a few volts to about 10 millivolts by including the nonlinear elements of the amplifier in its negative feedback loop.

Selective Bandpass I.F. Amplifiers; Use of "Ferroxcube" Pot Cores in Conjunction with Negative Feedback. J. S. Belrose. *Wireless World*, Sept., 1956, pp. 435–438.

Reflected Impedances in Junction Transistor Amplifiers. Francis Oakes. *Proc. Inst. Electronics*, Fourth Quarter, 1955, pp. 7–24. Analysis of impedances reflected from the input into the output circuit and vice versa. Numerical formulas are presented for grounded base, grounded emitter, and grounded collector amplifiers.

Antennas

The Use of a Horizontal Dipole as a Direction Finding Aerial. G. Millington. *Marconi Rev.*, 3rd Quarter, 1956, pp. 97–118. Investigation of the effect of the vertical component of a transmitting dipole on a horizontal dipole used as a direction finder. The errors discussed are those due to field components which may exist under the ideal conditions assumed from a smooth homogeneous earth as distinct from site and instrument errors.

Wide-Angle Scanning Performance of Mirror Aerials. J. F. Ramsay and J. A. C. Jackson. *Marconi Rev.*, 3rd Quarter, 1956, pp. 119–140. Experimental investigation of the scanning performance of two mirror aerials—the coma-corrected zoned mirror and the spherical mirror.

Circuits & Components

An Evaluation of Relays for Low-Level Switching. Vincent F. Argento. *Sperry Eng. Rev.*, July-Aug., 1956, pp. 18–22. Investigation to determine methods for improving reliability of relays through improvements in materials, manufacturing and test procedures, and quality control.

Effects of Radiation on Electronic Components. R. D. Shelton. *Tele-Tech*, Sept., 1956, pp. 57, 123–126. Discussion of damage resulting from nuclear radiation as a function of the type and energy distribution of the radiation as well as temperature, humidity, stress, and rate of irradiation. Includes effects on wire and connecting cables, vacuum tubes, resistors, capacitors, and other components.

Dielectrics

Mechanical Properties of Plastics Dielectrics. Bryce Maxwell. *Elec. Mfg.*, Sept., 1956, pp. 146–153. Analysis relating the effects of environmental conditions to time and temperature ranges to furnish design data for plastic dielectrics.

A Homogeneous Dielectric Sphere as a Microwave Lens. G. Bekefi and G. W. Farnell. *Can. J. Phys.*, Aug., 1956, pp. 790–803. 28 refs. USAF-supported computations applying geometric optics and the diffraction theory of optical aberrations to determine the feasibility of using a homogeneous dielectric sphere as a microwave lens.

Controlled Field Emission in Hexane. W. B. Green. *J. Appl. Phys.*, Aug., 1956, pp. 921–925. USAF-ONR-Army-sponsored experimental investigation of hexane to determine some of the potentialities of a liquid field-emission system.

Navigation Aids

Development Trends in Radio Navigation. Walter Stanner. *Interavia*, July, 1956, pp. 511–513. Discussion of available navigation systems, including D/F systems, rotating and directional beacons, and distance measuring and long baseline systems.

Bordradargeräte in der Verkehrsluftfahrt. Karl Röhrich. *Luftfahrttechnik*, July 15, 1956, pp. 122–126. In German. Evaluation of radar installation in aircraft and of its practical application to navigation and collision prevention. Includes analysis of radar fundamentals, with details of the radar antenna, emitter, receiver, automatic antenna stabilization, iso-echo representation, reception, visual representation, the influence of the wave length on the reflection factor, and other practical applications.

Theorie und Technik des Instrumenten-Landesystems (ILS). Karl Bärner. *Luftfahrttechnik*, Sept. 10, 1955, pp. 74–84. In German. Theoretical and practical factors of instrument landing systems.

Entwicklungsstand der Flugregelungen. Gerald Klein. *Luftfahrttechnik*. Apr. 15, 1956, pp. 62–70. 10 refs. In German. Survey of developments in automatic navigation and control systems.

Radar

High Power Breakdown of Microwave Structures. George K. Hart, Frank R. Stevenson, and Morton S. Tanenbaum. *Sperry Eng. Rev.*, July-Aug., 1956, pp. 8–13. Theoretical and experimental investigation of the breakdown of several basic microwave components. Data obtained are analyzed, and graphs useful in predicting the breakdown of these and similar structures are discussed.

Stable Local Oscillator for S-Band Radar. W. J. Dauksher. *Electronics*, Sept., 1956, pp. 179–181. Description of a tunable crystal oscillator, followed by a cascade of harmonic amplifiers for output at desired frequency, which has good short-term stability for mti radar local-oscillator service, obtains a continuous frequency range of 1.3 per cent by using six crystals with motor-driven switching and afc systems, and whose harmonic-amplifier cascade has sufficient power output to allow for drop-off in efficiency when operated off resonance.

Interpretation of the Height-Versus-Time Presentation of Radar Echoes. V. G. Miles. *J. Meteorology*, Aug., 1956, pp. 362–368. USAF-sponsored study of the factors influencing the exact form in which echoes appear on the record produced by AN/APS-34 and AN/TPQ-6 radars used with fixed, vertically directed beams to detect clouds and precipitation. The echoes are continuously recorded against a scale of height by a facsimile recorder, and the result, over a period of time, is a chart of echoes on a diagram whose ordinate is height and whose abscissa is time.

Semiconductors

Power Regulation by Semiconductors. F. H. Chase. *Elec. Eng.*, Sept., 1956, pp. 818–822. Discussion of power regulation using silicon junction diodes as reference potentials and junction transistors as the controllable elements.

Characteristic Tracer for Power Transistors. S. Kramer and R. Wheeler. *Tele-Tech*, Sept., 1956, pp. 58, 59, 86 ff. Presentation of design considerations and experimental results.

Behaviour of the Transistor at High Current Densities. F. H. Stieltjes and L. J. Tummers. *Philips Tech. Rev.*, July 27, 1956, pp. 61–68. Theoretical investigation to show that the simple theory of the junction transistor is not applicable at high current densities. Results point out methods for reducing the effect of such high densities.

Avalanche Breakdown Voltage in Silicon Diffused *p-n* Junctions as a Function of Impurity Gradient. H. S. Veloric, M. B. Prince, and M. J. Eder. *J. Appl. Phys.*, Aug., 1956, pp. 895–899. Development of a method showing that the significant parameters are the resistivity and the time and temperature of diffusion. Statistical analysis points out that the mean breakdown voltage of a large group of units can be predicted within 2 per cent. The method fails for very low or high resistivity material.

Equipment

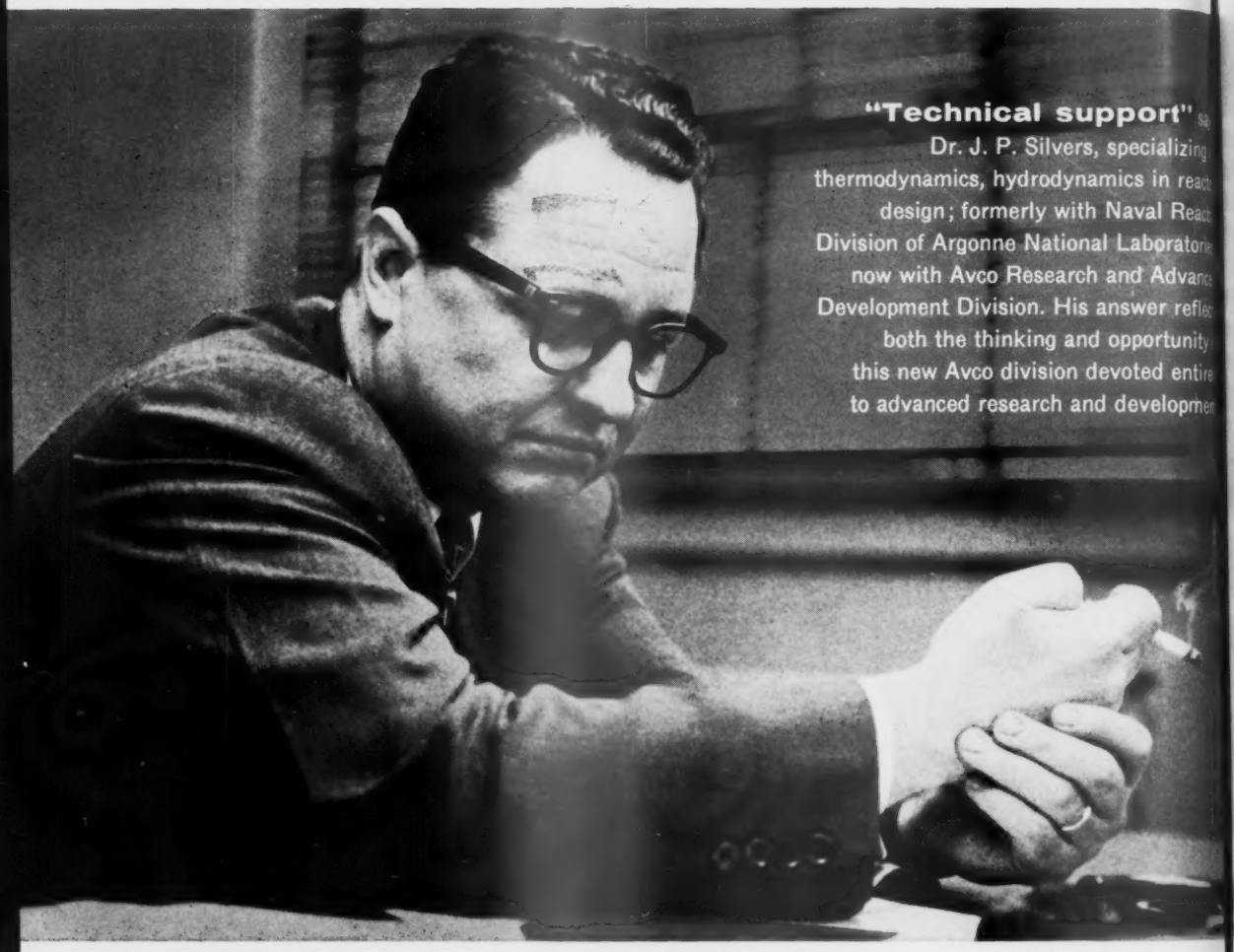
Electric

Electrical Equipment for Aircraft. E. A. Smith. *Aeronautics*, Aug., 1956, pp. 86–95. Developmental discussion with emphasis on problems associated with heat, switch gear, cable protection of systems, power utilization, radio, and other related subjects encountered now and to be met in the future.

Indukcyjne Przekaźniki Nieograniczonych Kątów Obrotu i ich Zastosowanie w Automatyce Lotniczej. II. (Induction Transmitters of Unlimited Angular Motion and Their Use in Aviation Automatics.) Janusz Morawski. *Tech. Lotnicza*, July-Aug., 1956, pp. 100–105. 10 refs. In Polish.

(*Continued on page 152*)

what helps an engineer grow?


"Technical support" say
Dr. J. P. Silvers, specializing
thermodynamics, hydrodynamics in reacto
design; formerly with Naval Reacto
Division of Argonne National Laboratorie
now with Avco Research and Advance
Development Division. His answer reflec
both the thinking and opportunity
this new Avco division devoted entire
to advanced research and developmen

"An engineer should be given plentiful technical assistance. His potential cannot be fully realized when his creative energies are consumed by routine duties."

Helping talented engineers and scientists reach full effectiveness is the best way we, at Avco Research and Advanced Development, know of helping our own growth. For outstanding men, Avco's long-range expansion—in missiles and in all the physical sciences—offers unprecedented opportunity. Write: Dr. Lloyd P. Smith, General Manager, Room 413L, Avco Research and Advanced Development Division, 20 S. Union St., Lawrence, Mass., MUrdock 8-6011.

WANTED
Leaders in the exploitation of new areas of Science

Physical Scientists
Advanced degree preferred in—Physics · Aerodynamics · Electronics · Metallurgy · Physical Chemistry · Mathematics · Thermodynamics

Engineers
Electronic · Mechanical · Aeronautical
Chemical

avco Research and Advanced Development division

ort" sp
cializing
s in reach
val Reach
boratorie
Advance
ver reflec
portunity
ed entire
velopmen
as of Science
ysics · Aero-
y · Physical
modynamics
utical
ent
ion

INTERNATIONAL AERONAUTICAL ABSTRACTS

A Review of Worldwide Scientific and Technical Literature

Selected and prepared by the IAS Staff from currently released material received in the IAS Library. This research is supported by the Air Force Office of Scientific Research of the Air Research and Development Command. Address inquiries concerning this literature to the IAS Library.

PUBLISHED MONTHLY BY THE AERONAUTICAL ENGINEERING REVIEW
Official Publication of the Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

Volume 1, Number 11 November, 1956

AERODYNAMICS

AERODYNAMIC MIXING DOWNSTREAM FROM LINE SOURCE OF HEAT IN HIGH-INTENSITY SOUND FIELD. Appendix A, B - DERIVATION OF EQUATIONS APPEARING IN THEORETICAL ANALYSIS. Appendix C - FLOW AND SOUND-FIELD MEASUREMENTS. Appendix D - INSTANTANEOUS-TEMPERATURE MEASUREMENTS WITH RESISTANCE THERMOMETER. Appendix E - INSTANTANEOUS-TEMPERATURE MEASUREMENTS WITH HOT-WIRE ANEMOMETER. W. R. Mickelsen and L. V. Baldwin. US, NACA TN 3760, Aug., 1956. 75 pp. 13 refs. Results of theoretical and experimental investigation presented for the cases of sound fields with a sinusoidal wave form and with a nonsinusoidal wave form for small and large wake deformations. Theoretical work involves a kinematic analysis of the motion of the molecular-diffusion wake to derive equations for the time variation of temperature and the time-mean temperature at points throughout the mixing region, and analytic results indicate that standing sound waves displace the diffusion wake in a manner similar to the displacements of a flag waving in a harmonic mode. Experiments are conducted in a low-turbulence airstream with superimposed transverse velocity fluctuations associated with a standing wave.

EXAMPLES OF WAVE DRAG CALCULATION BY APPLICATION OF FOURIER ANALYSIS ABOUT A STREAMWISE AXIS. E. W. Graham. Douglas Rep. SM-19529, Jan., 1956. 29 pp. 14 refs. Theoretical investigation using Hayes' method for determining the drag of singularities, and applying Fourier analysis both to the singularities distributed in space (representing aircraft components) and to their projections on a streamwise axis in order to calculate some examples of wave drag. Included in the investigation is a study of a "ring" wing represented by singularities in a circular cylindrical shell with axis in the flight direction, taking into account the angular distribution of radial force to obtain the optimum distribution for producing a given net lift; discussion of a pseudovolume for force distributions which produce wave systems similar to those created by bodies of revolution; and Fourier analysis of the thickness drag of a planar wing with reduced aspect ratio of unity. Comparison of the theoretically obtained thickess drag with the known wave drag indicates that very few terms in the Fourier series may be required in evaluating drag for aspect ratios of this order. Further results show that an axially symmetric distribution of tangential forces has zero wave drag; such a situation would be approached in the case of a missile with many fins deflected to produce a rolling moment.

LOW SPEED STATIC AND FLUCTUATING PRESSURE DISTRIBUTIONS ON A CYLINDRICAL BODY WITH A SQUARE FLAT PLATE AIRBRAKE. T. B. Owen. Gt. Brit., RAE TN Aero. 2396, Jan., 1956. 18 pp. Measurements of mean values and fluctuations of the static pressure on the surface of a body fitted with an airbrake. Results indicate a rapid increase in both the mean amplitude of the pressure fluctuations and the area of the body affected, if the brake angle is increased beyond 50°. At lower frequencies a large increase in amplitude occurs between 40° and 50°, which is associated with the appearance of a regular shedding of turbulent eddies. On the model used with an average gap of about 27% of the length of the brake, the shedding frequencies are in close agreement with those measured on an isolated plate at smaller brake angles and slightly higher than those on an isolated plate at higher brake angles.

Aerothermodynamics

INVESTIGATION OF THE LAMINAR AERODYNAMIC HEAT-TRANSFER CHARACTERISTICS OF A HEMISPHERE-CYLINDER IN THE LANGLEY 11-INCH HYPERSONIC TUNNEL AT A MACH NUMBER OF 6.8. D. H. Crawford and W. D. MacCauley. US, NACA TN 3706, July, 1956. 38 pp. 18 refs. Measurements using data from transient noniso-

thermal temperature distributions, with results of pitot profiles verifying that the local Mach Number or velocity outside the boundary layer required in the theories may be computed from the surface pressures by using isentropic flow relations and conditions immediately behind a normal shock. Further results indicate that the experimental pressure distribution at a Mach Number of 6.8 is closely predicted by the modified Newtonian theory, and that the velocity gradients calculated by using this modified theory at the stagnation point vary with Mach Number and are in good agreement with those obtained from measured pressures for Mach Numbers from 1.2 to 6.8. At the stagnation point, the Sibulkin theory using the diameter and conditions behind the normal shock, is in good agreement with the experiment when the velocity gradient at the stagnation point appropriate to the free-stream Mach Number is used. The experimental heat-transfer coefficients are slightly less over the whole body than those predicted by the theory of Stine and Wanlass for an isothermal surface, but for stations within 45^{o} of the stagnation point the heat-transfer coefficients can be correlated by a single relation between the local Stanton and Reynolds Numbers. Reynolds Number range for the experiments is from 1.09×10^{5} to 1.03×10^{6}.

USE OF THE SHOCK TUBE WALL BOUNDARY LAYER IN HEAT TRANSFER STUDIES. Robert Bromberg. Jet Propulsion, Sept., 1956, pp. 737-740. Development of a technique for studying boundary layer characteristics in gases at extremely high temperatures, including dissociation. Results show that the boundary layer developed on a plane surface due to the passage of the shock wave is inherently different from the usual boundary layer, but, assuming relatively well-controlled conditions, yields a convenient device for testing boundary-layer theories under severe heat transfer and shear stress conditions.

THE BINARY-MIXTURE BOUNDARY LAYER ASSOCIATED WITH MASS TRANSFER COOLING AT HIGH SPEEDS. J. R. Baron. MIT NSL TR 160, May, 1956. 280 pp. 80 refs. Theoretical investigation of the laminar boundary layer flow of a mixture in which a coolant with different physical properties is injected into the primary gas flow. Analysis is based on the equations of change resulting from the Enskog solution of the Boltzmann equation. The Schmidt Number is introduced as characteristic of the relative magnitude of the momentum and mass transfer rates by molecular action, and an analysis for the case in which both Prandtl and Schmidt Numbers are identically unity results in an extended form of the familiar quadratic relation between temperature and velocity for flow over a plate. Ordinary differential equations result from a transformation involving a modified Blasius parameter which includes the Dorodnitzyn variable, and these are solved exactly (using a Whirlwind digital computer) for both helium and carbon dioxide injected into an air flow of zero pressure gradient. An integral method is developed to illustrate the mixture influence downstream of an injection region and the consequent approach to homogeneous gas flow at infinity. Includes a brief investigation of boundary layer stability.

Boundary Layer

EQUIPMENT USED FOR BOUNDARY LAYER MEASUREMENTS IN FLIGHT. I - THE DESIGN AND CONSTRUCTION OF A LARGE MULTITUBE MANOMETER FOR USE IN FLIGHT. II - TWO FIXED HEAD TYPE COMBS FOR BOUNDARY LAYER INVESTIGATIONS. F. M. Burrows. Coll. of Aeronautics, Cranfield, Rep. 49, July, 1956. 30 pp. The manometer, which is installed in the rear fuselage of an Avro Lancaster, is designed to cope with all the aerodynamic measurement requirements to be satisfied under test conditions, and to overcome the difficulties associated with making such observations in flight. The two types of combs described are designed to measure the boundary-layer velocity profile and the total head distribution at, near to, and along the wing surface respectively for a fairly wide range of experimental conditions in which the flow can assume any characteristics between those of a thin laminar to a thick turbulent boundary layer, or more remotely, a layer in separated flow. The airplane for which both instruments are designed is used as a test vehicle for a series of in-flight investigations of the behavior of the three-dimensional boundary layer on a swept-back wing at moderately high Reynolds Numbers. It is shown that the equipment can be modified for other applications.

STRATO LIMITE COMPRESSIBILE SUL CORPO DI RIVOLUZIONE. Dante Cunsolo. L'Aerotecnica (Rome), June, 1956, pp. 160-176. 13 refs. In Italian. Discussion of different methods for solving compressible boundary-layer problems, particularly those of bodies of revolution. Includes description of the Mangler transformation for converting axial-symmetrical problems into two-dimensional problems.

INFLUENZA DI UN VENTO LATERALE SULLO STRATO LIMITE DI CORRENTE COMPRESSIBILE AD ALTA VELOCITÀ CHE INVESTE UN OSTACOLO CILINDRICO (ALA IN DERIVA O A FRECCIA). Aldo Castagno. L'Aerotecnica (Rome), June, 1956, pp. 152-159. In Italian. Theoretical investigation of the side-wind influence on the boundary layer on a cylindrical body (yawed- or swept-wing) in a high-speed compressible stream. The effect on a yawed, adiabatic infinite wing in a fluid of unit Prandtl Number is considered, and the velocity and viscous distributions are calculated for a flat plate and for the general case of an airfoil with possible boundary-layer separation.

WIND-TUNNEL OBSERVATIONS OF BOUNDARY-LAYER TRANSITION ON A WING AT VARIOUS ANGLES OF SWEEPBACK. A. Anscombe and L. N. Illingworth. Gt. Brit., ARC R&M 2968, 1956. 9 pp. BIS, New York, $0.54. Results of tests indicating that at each sweepback angle above 25^{o}, a critical speed exists within the speed range of the

tunnel (400 ft./sec.) at which striations appear within the laminar boundary layer, while the transition line itself lies at 50% to 60% chord. As the speed is further increased, transition begins to move forward, occurring finally close to the leading edge. The wind speeds, at which the striations appear and the forward movement of transition begins, decrease with increasing sweepback angle. The sweepback angles considered range from zero to 50°, and the wing is of constant chord.

L'INTERFERENZA FRA ONDE D'URTO E STRATO LIMITE. A. Eula. L'Aerotecnica (Rome), June, 1956, pp. 177-217. 28 refs. In Italian. Review of the difficulties involved in solving the theoretical problems associated with the interference between shock waves and boundary layer; summary of experimental methods used in the transonic and supersonic regions; and detailed examination of the Ritter-Kuo theoretical method for justifying the observed phenomena. Includes a schematic description of the phenomena and a critical analysis of test results. Theoretical approaches other than those derived by Ritter and Kuo - some of which take viscosity into account, and some which neglect it - are also discussed. The Crocco-Lees theory on the interference between dissipative and quasi-isentropic flows is reviewed, and it is shown that the results of this theory correlate well with experimental data.

ON TRANSITION FROM LAMINAR TO TURBULENT FLOW. F. R. Hama, J. D. Long, and J. C. Hegarty. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-81 (AFOSR TN 56-381), Aug., 1956. 50 pp. 23 refs. Experimental investigation of the flow phenomena associated with boundary-layer transition to obtain qualitative information by means of water-tank observations which permit direct surveillance of the entire flow pattern and which, because of the lower kinematic viscosity of water as compared to air, also allow the use of a lower flow velocity to attain a comparable Reynolds Number in air and make a slow-motion appraisal possible through the expansion of the flow-phenomena time scale inversely proportionate to the kinetic velocity. Results, which supplement quantitative wind-tunnel data, indicate that a two-dimensional discrete vortex line - considered to be the consequence of an amplified perturbation wave - has a strong tendency, in shear flows, to form a three-dimensional vortex loop with a marked transverse wave length. Observations further reveal that the formation and development of a vortex loop must occur before a turbulent spot can originate near the top of a vortex loop or near the outer edge of the boundary layer, and that this formation and development provides the guiding principle of laminar-to-turbulent transition in wakes and jets as well as in the boundary layer. An efficient turbulence-stimulation device is proposed as an application of these results.

Control Surfaces

THE DETERMINATION OF AILERON EFFECTIVENESS. R. R. Duddy. Gt. Brit., RAE TN Aero. 2462, June, 1956. 10 pp. Results of flight tests over a wide range of lift coefficients and at low subsonic Mach Numbers to determine aileron effectiveness derivatives. Comparison is made with wind tunnel tests, and estimates compiled from the RAeS Data Sheets of the four aircraft tested, one having zero sweepback and the other three quarter chord sweep from about 37° to 45°. Results indicate that the agreement between the three systems is not particularly good. On three aircraft the value of the aileron effectiveness measured in flight appears always lower than the estimated value, and nearly always lower than the tunnel value. On the fourth aircraft the flight values are higher than the wind tunnel values. The tunnel tests show the reduction of effectiveness with increasing lift coefficient, and in general are in closer agreement with flight values than the estimated values.

Fluid Mechanics & Aerodynamic Theory

CONICAL TECHNIQUES FOR INCOMPRESSIBLE NONVISCOUS FLOW. H. J. Stewart and A. I. Ormsbee. J. Aero. Sci., Nov., 1956, pp. 1,029-1,036. Analysis of incompressible potential fields which are homogeneous of order zero. Complex conical velocity functions (U, V, W) are defined, whose real parts represent the physical velocity components (u, v, w). Relations governing the velocity functions are derived, restrictions on the types of singularities these functions may have are discussed, and techniques are developed for the superposition of conical fields to obtain nonconical, physically significant flows associated with constant strength source and vortex sheets of finite extent. The constant-strength source sheets are applied to the construction of aerodynamic models of thin nonlifting wings of polygonal flow form and cross section. The constant-strength vortex sheets are used to construct models of thin wings with constant pressure distribution.

THE ROLLING-UP OF A VORTEX SHEET. Marvin Stern. ZAMP, July 25, 1956, pp. 326-342. Analysis of the problem of a rolled-up vortex sheet behind a wing of finite span, treating the problem as a two-dimensional time dependent flow associated with the semi-infinite vortex sheet. Differential equations are obtained describing the flow fields that hold over the whole plane, rather than just the conditions that are to be satisfied locally in the spiral case. Agreement is shown with the results of the Kaden's solution for the spiral case.

AERODYNAMIC INVESTIGATION OF A PARABOLIC BODY OF REVOLUTION AT MACH NUMBER OF 1.92 AND SOME EFFECTS OF AN ANNULAR SUPERSONIC JET EXHAUSTING FROM THE BASE. E. S. Love. US, NACA TN 3709, Sept., 1956. 62 pp. 15 refs. Includes: measurements - with the jet inoperative - of lift, drag, pitching moment, radial and longitudinal pressure distributions, and base pressures; and measurements - with the jet in operation - of the pressures over the rear of the body with the primary variables being angle of attack, ratio of jet to free-stream velocity, and ratio of jet to stream pressure. Results, which are compared to those theo-

retically derived, indicate that the maximum effects of the jet obtained at the lower ratio of jet-to-stream velocity and at the highest ratio of jet-to-stream pressure, amount to a slight decrease in foredrag, a reduction in lift, and a shift of center of pressure in a destabilizing direction.

AN EXPERIMENTAL INVESTIGATION OF THE FLOW OVER BLUNT-NOSED CONES AT A MACH NUMBER OF 5.8. R. M. Machell and W. T. O'Bryant. GALCIT Memo. 32, June 15, 1956. 61 pp. 12 refs. Observation of shock shapes and measurement of static pressures over a range of Reynolds Numbers per inch from 97,000 to 238,000 and for angles of yaw from 0° to 8°; and determination of the significant parameters governing pressure distribution through the use of six combinations of the bluntness ratios 0.4, 0.8, and 1.064 with the cone half angles 10°, 20°, and 40°. Results show that the pressure distribution on the spherical nose for both yawed and unyawed bodies is predicted quite accurately by the modified Newtonian theory and that cone half angle is the significant parameter in determining the pressure distribution near the nose-cone junction and over the conical afterbody. Integrated results for the pressure foredrag of the models at zero yaw compare closely with predictions by the modified Newtonian approximation, except for models with large cone angles and small nose radii where the drag approaches the value given by the Taylor-Maccoll theory for sharp cones.

ON SUPERSONIC ROTATIONAL FLOW BEHIND STRONG SHOCK WAVES. II - FLOW PAST OGIVES OF REVOLUTION. Appendix I - TRANSFORMATION OF CROCCO'S EQUATION TO POLAR COORDINATES. Appendix II - EXPANSION OF VELOCITY PERTURBATIONS u' AND v'. Appendix III - THE FIRST APPROXIMATION DIFFERENTIAL EQUATION. Abraham Kogan. Technion Res. Devel. Found., Haifa, TR (AFOSR TN 56-316), Jan. 15-July 15, 1956. 35 pp. Method of successive approximations is applied to a solution for an ideal fluid in axially symmetric flow around ogives of revolution at supersonic Mach Numbers. A procedure for obtaining correct successive approximations to the flow in the tip region is indicated. A first order approximation is worked out in detail, and it is shown that the mathematical singularity of the first order approximation near the surface of the ogive is avoided by the introduction of Crocco's stream function.

EXTREMUM PRINCIPLES FOR SLOW VISCOUS FLOW AND THE APPROXIMATE CALCULATION OF DRAG. R. Hill and G. Power. Quart. J. Mech. & Appl. Math., Sept., 1956, pp. 313-319. Proof of a complementary pair of extremum principles in their hydrodynamical context and illustration of their application to obtain arbitrarily close approximations from above or below to the total rate of energy dissipation and hence to the drag on a translated or rotated body in the fluid. One of the principles relates to the class of all displacement fields consistent with the boundary conditions on displacement; the other, to the class of all equilibrium states of stress consistent with the boundary conditions on stress.

ÜBER EIN CHARAKTERISTIKENVERFAHREN ZUR ANGENÄHERTEN BERECHNUNG DER UNSYMMETRISCHEN ÜBERSCHALLSTRÖMUNG UM MEHRERE HINTEREINANDER ANGEORDNETE RINGFÖRMIGE KÖRPER. Jürgen Zierep. ZFW, Sept., 1956, pp. 290-300. In German. Extension of the Haack and Erdmann-Oswatitsch method of characteristics for calculating approximately the asymmetric supersonic flow around a single ring, neglecting the area under the influence of the trailing edge of the ring, in order to derive a solution of the problem of characteristics of the initial value for this area - which originates from the trailing edge of the ring due to the local pressure drop and requires the pressure to be continuous while passing through the surface and the flow vector to lie in a plane tangential to this surface - for the linear terms of the angle of incidence ϑ. The ratio of the lift and ϑ for the limit $\vartheta \to 0$ of an annular wing, consisting of a number of rings placed over the projectile, are calculated, using the new solution. Results of this calculation, confirmed by experimental data, indicate that the lift of a multistage annular wing can be considerably increased compared with that of a single annular wing of the same overall length.

AN EXPERIMENTAL STUDY OF THE ONE-DIMENSIONAL REFRACTION OF A RAREFACTION WAVE AT A CONTACT SURFACE. I. J. Billington. J. Aero. Sci., Nov., 1956, pp. 997-1,006. 12 refs. The rarefaction wave generated by the bursting of the shock-tube diaphragm is used as the incident wave in the interaction with an air-and-helium or air-and-argon contact surface. Results indicate that the initial rarefaction wave in the shock tube deviates considerably from that predicted by ideal shock-tube theory, and that, when this deviation is taken into account, the conclusions of the rarefaction-wave refraction show good agreement with the theory. Results also verify the theory that a compression wave is reflected if argon is used.

INTERACTION OF GRIDS WITH TRAVELING SHOCK WAVES. D. S. Dosanjh. US, NACA TN 3680, Sept., 1956. 81 pp. 27 refs. Theoretical and experimental investigation based on measurements, recorded by means of shadowgraphic and hot-wire techniques, of the emergence, growth, and speeds of the transmitted and reflected shock fronts produced when the incident wave splits after colliding with a grid mounted in the path of traveling shock waves in shock tube. The pressure-drop coefficient, calculated from the speeds of the incident shock, as well as from those of the transmitted and reflected shocks, bears out the observation that the grid chokes when strong incident shocks are used, and a simplified semiempirical analysis of this phenomenon is undertaken. It is further shown that the reflected shock wave advances upstream against the drift flow associated with the incident shock wave and that the transmitted shock front is reflected from the closed far end of the shock tube. The shadowgraphs of the interaction of the advancing reflected-transmitted shock front with the turbulent flow field caused by the passage through the grid of

the flow behind the reflected shock front, are examined, and the observed change in speed of the reflected-transmitted shock is discussed. Conclusions regarding the state of the flow downstream of the grid are drawn from examination of oscillograms of the hot-wire response of various transient flow regions.

INFLUENCE D'UNE RÉDUCTION DU DÉBIT CAPTÉ SUR LA RÉSISTANCE EXTERNE D'UNE ENTRÉE D'AIR SUPERSONIQUE DE RÉVOLUTION. J. Nicolas. La Recherche Aéronautique, July-Aug., 1956, pp. 33-36. In French. Analysis of a detached shock wave generated at the supersonic air intake and of the resulting modification of the aerodynamic resistance. Calculations are performed for 1,4 and 1,6 Mach Numbers, and the effect of detached shocks on thrust is emphasized.

THE ACCURACY OF THE METHOD OF CHARACTERISTICS FOR PLANE SUPERSONIC FLOW. M. G. Hall. Quart. J. Mech. & Appl. Math., Sept., 1956, pp. 320-333. Analysis of the mechanism by which errors are propagated through a computation, determination of the effects of various types of errors, and outline of a method for planning computations to achieve specified accuracy with minimum labor. Consideration is given to the error problem for computations of two-dimensional, steady, homentropic, irrotational, supersonic flow of a perfect gas. The conjecture that the principal feature of the domain of influence of an error should be a direct propagation along Mach lines emanating from the point where the error is introduced and that the effects in between should be comparatively negligible is confirmed and this verification indicates that the domain of dependence of a point cannot even approximately be identified with the two Mach lines converging to the point, except for the special case of the statistical effect of rounding errors.

Internal Flow

THE EFFECTS OF DISSOCIATION AND IONIZATION ON COMPRESSIBLE COUETTE FLOW. H. W. Liepmann and Z. O. Bleviss. Douglas Rep. SM-19831, May, 1956. 42 pp. Investigation of the compressible Couette flow for studying the effects of a variation of the gas properties upon recovery temperature, skin friction, and heat transfer, in order to further understand the flow in a high-speed laminar boundary layer. The recovery temperature at the stationary wall is calculated as a function of Mach Number at the cool moving wall for oxygen and nitrogen. Analytical results are obtained using a simple viscosity-enthalpy power law. Two extreme cases are studied, one with the stationary wall insulated, and the second with both wall temperatures equal. Skin friction, heat transfer, and velocity distributions are studied as functions of the Mach Number and the exponent of the power law. To illustrate the effects of dissociation, enthalpy, temperature, degree of dissociation, density, and mass flow distributions are calculated for oxygen at $M = 2$ and $M = 20$, using a power of 1/2.

DER KRAFTANGRIFF BEI STRAHLTRIEBWERKEN UND IHREN VERKLEIDUNGEN. Gerhard Schulz. ZFW, Sept., 1956, pp. 285-290. In German. Analysis of the forces acting on a jet engine and its cowling. It is shown that the lifting forces act partly at the cross section of the intake, partly at the outer contour, and partly at the inside of the engine. The various components of drag - particularly the induced drag - are defined, and the following results concerning the flow at the intake at the noze of the nacelle are indicated: in cases of an unfavorable contour shape, the additional drag due to a bad flow at the intake may exceed the drag of the nacelle; the lift acting on the nacelle causes a shift of the neutral point of the airplane which may be of considerable magnitude. Results of an investigation into the amount of thrust taken by the actual engine and that taken by the cowling indicate that the latter component depends on the speed of flight, the cowling shape, and the temperature level.

EFFECTS OF REYNOLDS NUMBER ON THE FLOW OF AIR THROUGH A CASCADE OF COMPRESSOR BLADES. H. G. Rhoden. Gt. Brit., ARC R&M 2919, 1956. 34 pp. BIS, New York, $1.62. Investigation of three cascade types for axial - flow compressor blades at camber angles of 20°, 30°, and 40°, respectively. Measurements are made of the distribution of static pressure over the central cross section of the middle blade of each cascade, together with traverses of static pressure, total head, and angle of flow at inlet and outlet to each cascade in the plane of central cross section. Tests cover a range of Reynolds Numbers from 0.3×10^5 to 5×10^5, based on inlet air velocity and blade chord. Results show numerous cases of laminar boundary-layer separation at low Reynolds Numbers occurring on the convex surfaces, and a few cases of turbulent separation at higher Reynolds Numbers. Cases of laminar separation from the cascade surface of the blades can also be seen. The type of pressure distribution likely to give good performance over a wide range of Reynolds Numbers is discussed.

THE USE OF PERFORATED INLETS FOR EFFICIENT SUPERSONIC DIFFUSION. J. C. Evvard and J. W. Blakey. US, NACA TN 3767, Sept., 1956. 35 pp. Experimental investigation at a Mach Number of 1.85 on a preliminary model of a perforated diffuser having a geometric internal contraction ratio of 1.49 (the isentropic value) and description of the method used. Includes a theoretical discussion of the flow coefficients as well as the size and spacing of the perforations. Total-pressure recoveries of 0.931, 0.920, and 0.906 are obtained at angles of attack 0°, 3°, and 5°, respectively.

PRELIMINARY MEASUREMENTS OF NONSTEADY VELOCITIES IN A SINGLE STAGE AXIAL-FLOW COMPRESSOR. Hsuan Yeh, H. M. Croner, and D. E. Andrews. USAF WADC TR 55-249, June, 1956. 41 pp. 15 refs. Experimental investigation conducted at one operating condition near the design point of the compressor and well to the right of the peak in the head-capacity curve,

and with the radial location of all probe points arbitrarily fixed at 4-3/16-in. from the blade tip - roughly near the middle span of the blade - to provide information when the blades are not near stalling. Results are interpreted analytically. These results, obtained with Reynolds Number of approximately 20,000 (based on blade-chord length), yield data on the intensity and decay of wakes, the induced velocity upstream of the rotor, and the turbulence level throughout the machine. The separation of periodic and random fluctuations, the wake, the induced velocities due to a moving cascade (including the bound and the trailing vortices), and the fluctuation intensity behind a rotor are considered theoretically.

RESULTS OF SYSTEMATIC INVESTIGATIONS ON SECONDARY FLOW LOSSES IN CASCADES. III - SECONDARY FLOW LOSSES OF A TURBINE CASCADE FOR DIFFERENT SHAPES OF BLADE TIP AND BLADE FOOT. E. G. Feindt. Braunschweig Tech. Hochschule Inst. Strömungsmech., Rep. 54/32a, May 15, 1956. 32 pp. In English. USAF-sponsored experimental investigation, with results indicating that, for the gap used, the secondary flow losses at the tip and at the foot of the blade are nearly of the same magnitude and depend little on the blade loading or on the shape of the blade tip and blade foot. Measurements are given for a turbine cascade having constant solidity ratio, blade-length-to-blade-chord ratio, and gap, and having an NACA 8410 blade profile. Those blade-tip shapes - bluntly cut off, obliquely cut off to the pressure side, and obliquely cut off to suction side of the blade - are considered, along with three blade-foot shapes - without a fillet, with a fillet of small radius, and with a fillet of large radius. The blade loading is altered by changing the blade angle.

LAMINAR JET MIXING OF TWO COMPRESSIBLE FLUIDS WITH HEAT RELEASE. S. I. Pai. J. Aero. Sci., Nov., 1956, pp. 1,012-1,018. OSR-supported formulation of the problem and discussion of the solution, pointing out the important parameters. Includes detailed study of specific cases, such as jet mixing of one compressible fluid, isothermal jet mixing of two compressible fluids, and isovel jet mixing of two compressible fluids, with heat release. Analysis is based on the assumptions that the mixture may be considered as a continuous medium, that the fluids are perfect gases, and that the chemical reaction proceeds according to the Arrhenius rate law, neglecting back reaction.

A DETAILED EXPERIMENTAL COMPARISON OF AXIAL COMPRESSOR BLADES DESIGNED FOR FREE VORTEX FLOW AND EQUIVALENT UNTWISTED AND TWISTED CONSTANT SECTION BLADES. S. J. Andrews and H. Ogden. Gt. Brit., ARC R&M 2928, 1956. 20 pp. BIS, New York, $0.99. Evaluation of the performance of six stages of twisted or untwisted constant section blades tested in a compressor at low speeds. Comparison is made with six stages of equivalent free vortex blades. Results show that, in terms of maximum stage efficiency, the twisted constant section blades are 0.5% better than the free vortex blades and the untwisted blades are 1.5% worse, but there is very little difference in the temperature rise characteristics. At values of flow coefficient greater than the design flow, the performance of the three sets of blades becomes almost identical. Incidental tests on the relation between pressure coefficient and Reynolds Number show that the maximum pressure coefficient falls to about half its original value for a change in Reynolds Number from 1.3×10^5 to 0.023×10^5, and this is accompanied by a reduction in the surge point flow coefficient.

DIAGRAMMES POUR LE CALCUL DES ÉJECTEURS À FLUX MOTEUR SUPERSONIQUE. E. Le Grivès, J. Fabri, and J. Paulon. France, ONERA NT 35, 1956. 27 pp. In French. Presentation of diagrams used for a rapid determination of the ejection characteristics of air-to-air supersonic exhaust nozzles. The choice of geometric and aerodynamic parameters satisfies several operating conditions in terms of actual and expected performance. Included is a supplementary diagram which compiles conditions of the optimal geometric configuration and of the optimal power source for each given application.

RELAZIONE SUI GETTI ASSIALSIMMETRICI DI GAS AD ALTA VELOCITÀ ED ELEVATA TEMPERATURA. Lodovico Pascucci. L'Aerotecnica (Rome), June, 1956, pp. 234-247. 33 refs. In Italian. Review of investigations of axially symmetric gas jets at high speeds and high temperatures, and classification of these studies according to the assumptions on which they are based. Includes analysis of special cases. The initial central zone (heart) is considered separately from the mixing zone, and the latter is subdivided into still other zones according to the distance from the mouth. The pertinent assumptions, the equations of motion, and the simplifications which have been introduced into the calculations are given for each zone, along with the velocity distributions and temperatures in the jet.

TABLES OF CHARACTERISTICS SLOPES FOR USE IN THE DESIGN OF NOZZLES FOR SUPERSONIC WIND TUNNELS. K. G. Winter. Gt. Brit., RAE TN Aero. 2444, May, 1956. 12 pp. Tabulation of slopes for numbers appropriate to Mach Numbers up to 4.5 given for characteristic intervals. With these slopes the coordinates of intersections may each be evaluated in one operation on a desk calculating machine.

Stability & Control

COMPARISON OF FLIGHT AND WIND-TUNNEL MEASUREMENTS OF HIGH-SPEED-AIRPLANE STABILITY AND CONTROL CHARACTERISTICS. W. C. Williams, H. M. Drake, and Jack Fischel. US, NACA TN 3859, Aug., 1956. 16 pp. Evaluation of the accuracy of wind-tunnel tests using data measured in flight on three swept-winged aircraft. In general the comparison shows that wind tunnels predict all trends in characteristics reasonably well. However, there are differences in exact values of parameters which could be attributed to dif-

ferences in the model caused by the method of support. The small size of the models may have some effect on measurements of flap effectiveness. When nonlinearities in derivatives occur during wind-tunnel tests, additional data should be obtained in the region of the nonlinearities in order to predict more accurately the flight characteristics. Also nonlinearities in static derivatives must be analyzed on the basis of dynamic motions of the airplane. Aeroelastic corrections must be made to the wind-tunnel data for models of airplanes which have thin surfaces and are to be flown in high dynamic pressure. Inlet effects can exert an influence on the characteristics, depending upon air requirements of the engine and location of the inlets.

AN OPTIMUM SWITCHING CRITERION FOR A THIRD-ORDER CONTACTOR ACCELERATION CONTROL SYSTEM. A. L. Passera and R. G. Willoh, Jr. US, NACA TN 3743, Aug., 1956. 46 pp. Derivation using analytical and analog-computer methods, with results compared to those of a linear system. The criterion is first determined for a second-order system in order to introduce the methods involved, and these methods are then applied to a third-order system descriptive of an ideal missile-acceleration control system. Includes transient responses of a third-order limited linear system which present a basis of comparison for the optimum third-order contactor control system.

Wings & Airfoils

CALCULATIONS OF THE FLOW OVER AN INCLINED FLAT PLATE AT FREE-STREAM MACH NUMBER 1. W. G. Vincenti, C. B. Wagoner, and N. H. Fisher, Jr. US, NACA TN 3723, Aug., 1956. 70 pp. 21 refs. Includes determination of the mixed flow about the lower surface of the plate by relaxation solution of the boundary-value problem in the hodograph plane, and description of a method of preliminary analysis required by the presence of the free-stream singularity. The supersonic flow on the upper side of the plate is found in the physical plane by a standard form of the method of characteristics. Results of the calculations, which are carried only as far as the end of the separated region that appears on the upper surface near the leading edge, are valid for an angle of attack of 13° and indicate that the large changes of flow field velocity that occur near the leading edge are confined to a very small part of the field, and that Guderley's earlier pressure distribution solution based on the transonic small-disturbance theory gives reasonably accurate results even at moderately large angle of attack.

PRESSURE AND BOUNDARY-LAYER MEASUREMENTS ON A TWO-DIMENSIONAL WING AT LOW SPEED. G. G. Brebner and J. A. Bagley. Gt. Brit., ARC R&M 2886, 1956. 47 pp. 10 refs. BIS, New York, $2.25. Experimental investigation with results integrated to give lift, drag, and aerodynamic-center characteristics in order to check (a) some calculation methods for the growth of the turbulent boundary layer and (b) a particular calculation method for the effect of a known boundary layer on the pressure distribution. A wing with 10% RAE 101 section at Reynolds Numbers of 1.6×10^6 and 3.2×10^6 is used, and the experimental data indicates that calculations (a) are handicapped by insufficient information about conditions in the transition region and near the trailing edge, but that, when the boundary layer is known; method (b) predicts the lift with good accuracy and the center of pressure accurately enough for practical purposes.

EXPERIMENTELLE UNTERSUCHUNGEN AN SCHIEBENDEN UND GEPFEILTEN FLÜGELN MIT NORMAL- UND LAMINAR-PROFILEN. K. H. Gronau and K. Nickel. DFL Inst. für Aero. Bericht No. 56/14, June 21, 1956. 105 pp. 10 refs. In German. Results of experimental investigations on two yawed and sweptback airfoils having normal NACA 0015 and laminar NACA 65_2-615 profiles and an aspect ratio of $\Lambda = 3$ and an angle of attack $\varphi = 45°$. Includes description of the experimental setup, and results of wake surveys, pressure distribution measurements, and three-dimensional boundary layer and laminar-turbulent transition, using flow visualization technique. It is pointed out that there is no tangible difference between the separation phenomena observed on both airfoils.

METHOD FOR CALCULATING THE AERODYNAMIC LOADING ON AN OSCILLATING FINITE WING IN SUBSONIC AND SONIC FLOW. Appendix A - NUMERICAL EXAMPLE OF THE LIFTING-SURFACE METHOD FOR A RECTANGULAR WING. Appendix B - TREATMENT OF CERTAIN INTEGRALS WHICH CONTAIN SINGULARITIES THAT ARISE IN THE CHORDWISE INTEGRATION. Appendix C - CALCULATION OF MOMENT ON DELTA WING. Appendix D - DESCRIPTION OF A MULTIPLE-LINE METHOD. H. L. Runyan and D. S. Woolston. US, NACA TN 3694, Aug., 1956. 76 pp. 37 refs. Analysis using the Falkner concepts for determining the air forces on an oscillating wing of general plan form in subsonic flow, including the limiting case of sonic flow. The loading on the wing is assumed to be given by a series containing unknown coefficients which satisfies various boundary conditions at the edges. The required integrations are performed by approximate means, and a set of simultaneous equations is obtained in terms of the coefficients in the loading series. Solution of this set of equations gives then the loading coefficients. The method is applied to rectangular and delta wings, and comparison is made with existing theory.

EXPERIMENTELLE UND THEORETISCHE UNTERSUCHUNGEN ÜBER DEN ABWIND UND SEITENWIND HINTER PFEIL- UND DELTAFLÜGELN. II - DAS SEITENWINDFELD. K. Gersten. DFL Inst. für Aero. Bericht No. 56/27, Aug. 25, 1956. 55 pp. 20 refs. In German. Theoretical and experimental investigation of downwash and induced sidewind behind swept and delta wings. Includes description and comparison of two methods used for calculating the circulation distribution, and devel-

opment of a new method for the determination of the induced sidewind at any location of a given leading edge and a given circulation distribution.

CALCULATION OF THE SHAPE OF A THIN SLENDER WING FOR A GIVEN LOAD DISTRIBUTION AND PLANFORM. J. H. B. Smith. Gt. Brit., RAE TN Aero.2410, Jan., 1956. 22 pp. Calculation of the shape of a wing of given planform necessary for producing a uniform distribution of chord loading across the span together with a chordwise lift distribution equal to that occurring in the two-dimensional flow around a flat plate. The linear inviscid potential flow theory is used, and the results are valid only for a small aspect ratio at any Mach Number or for sonic velocity at any aspect ratio. The slope of the wing is obtained in closed form as a function of two rectangular coordinates for wings with straight swept leading and trailing edges and streamwise tips. Numerical results are given for chordwise and spanwise variations of the slope of the wing surface measured in the chordwise direction at several stations, and chordwise wing sections are drawn for two particular planforms. These sections are found to have continuous tangents and not more than three discontinuities of curvature. Spanwise distributions of camber and local incidence are given for two wings.

EFFET DE DIÈDRE SUR UNE AILE DELTA EN RÉGIME SUPERSONIQUE. P. Germain and D. Vallée. La Recherche Aéronautique, July-Aug., 1956, pp. 13-20. In French. Study of dihedral effect on delta wings in stationary supersonic flow. The effects of lift and of the center of thrust are analyzed, and the case of a subsonic leading edge is considered.

THEORETICAL AND EXPERIMENTAL INVESTIGATIONS ON WING-BODY COMBINATIONS WITH DELTA WINGS IN SYMMETRICAL FLOW. K. Gersten and E. Truckenbrodt. Braunschweig Tech. Hochschule Inst. Strömungsmech., Rep. 56/20a, June 4, 1956. 45 pp. 25 refs. In English; translation of Bericht 56/20. ARDC-sponsored measurement of lift, drag, and pitching moment coefficients on a delta wing carried out in combination with bodies of various lengths and longitudinal cross-sections. The aspect ratio of the wing is 2.33 and the taper ratio is 0.125. The pitching moment of wing-body combinations have been calculated for delta wings of different aspect ratios and different body shapes. From these calculations the influence of the aspect ratio and the ratio of body width to wing span is obtained for a series of samples. The theoretical results are compared with the present measurements, and satisfactory agreement is found.

THE INTERFERENCE EFFECTS OF A BODY ON THE SPANWISE LOAD DISTRIBUTIONS OF TWO 45° SWEPTBACK WINGS OF ASPECT RATIO 8.02 FROM LOW-SPEED TESTS. Appendix A - CALCULATION OF THE BODY-INDUCED ANGLE OF ATTACK IN THE 19 X 1 METHOD. Appendix B - CALCULATION OF THE BODY EFFECTS BY THE 19 X 1 METHOD. A. P. Martina. US, NACA TN 3730, Aug., 1956. 47 pp. 18 refs. Experimental investigation of two wing-body combinations in the Langley 19-ft. pressure tunnel at a Reynolds Number of 4×10^6 and a Mach Number of 0.19 to determine the effects of wing incidence, wing fences, and flap deflection for a plane uncambered wing. Includes tests on an untwisted and uncambered wing, and on a twisted and cambered wing. Results indicate that the addition of the body to the plane wing increases the exposed wing loading at a given lift coefficient as much as 10% with the body at 0° incidence and 4% at 4° incidence; that the body-induced lift disappears near maximum lift in both cases; and that the bending-moment coefficients at the wing-body juncture increase about 2% with the body at 0° incidence and increase as much as 4% with the body at 4° incidence.

THREE-DIMENSIONAL TRANSONIC FLOW THEORY APPLIED TO SLENDER WINGS AND BODIES. M. A. Heaslet and J. R. Spreiter. US, NACA TN 3717, July, 1956. 72 pp. 32 refs. Review and comparison of transonic flow theory for slender wings and bodies of revolution with specific applications. The derivation of the integral equations for transonic flow is reexamined, giving special attention to conditions resulting from the presence of shock waves, and to the reduction of the relations to the special forms necessary for analyzing the sonic flow. In the vicinity of the body the disturbance field is shown to consist of a two-dimensional disturbance field extending laterally, and a longitudinal field that depends on the streamwise growth of the cross-section area. This result extends the Oswatitsch equivalence rule to lifting cases, provided the angle of attack is small relative to the thickness ratio. The correctness of the analysis is checked by an examination of the Yoshihara numerical solution for sonic flow around a slender cone-cylinder, and this solution in turn is checked by comparison with Solomon's experimental results. An expression is derived which permits the calculation of the difference in drag of two slender bodies having the same longitudinal distribution of cross-section area. Classes of wings and bodies are described for which the difference in drag is zero and the Whitcomb area rule can be applied.

GENERAL THEORY OF WAVE-DRAG REDUCTION FOR COMBINATIONS EMPLOYING QUASI-CYLINDRICAL BODIES WITH AN APPLICATION TO SWEPT-WING AND BODY COMBINATIONS. Appendix A - PRESSURE FIELD DUE TO DISTORTED BODY AT ANY SUPERSONIC SPEED. Appendix B - RELATIONSHIP BETWEEN SHAPE OF QUASI-CYLINDRICAL BODY AND STRENGTHS OF AXIAL MULTIPOLE DISTRIBUTIONS. Appendix C - ALTERNATE METHOD FOR DETERMINING BODY SHAPE FOR MINIMUM-DRAG COMBINATION. Appendix D - AN ANALYTICAL DETERMINATION OF MINIMUM-DRAG BODY SHAPE BY ALTERNATE METHOD. Appendix E - PRANDTL-GLAUERT TRANSFORMATION FOR WING-BODY COMBINATION. J. N. Nielsen and W. C. Pitts. US, NACA TN 3722, Sept., 1956. 79 pp. 12 refs. Application

of the Nielsen-Pitts theory of wing-body interference to the problem of minimizing the wave drag of a wing-body combination by utilizing radial body distortion. The method, which deals directly with pressure distributions and body shapes, is used to derive an integral equation for the body shape for minimum drag for each Fourier component of the radial body distortion, and is illustrated by a numerical example of its application to the wave-drag reduction of a 45° swept-wing and body combination utilizing a wing chord of three body radii and a span of six body radii with the leading and trailing edges assumed to be sonic and the wing section assumed to be biconvex.

REDUCTION OF DRAG DUE TO LIFT IN SUPERSONIC FLIGHT BY DISTRIBUTING LIFT ALONG A FUSELAGE. R. M. Licher. J. Aero. Sci., Nov., 1956, pp. 1,037-1,043. Method of reducing wing drag due to lift by using a specified wing plan form and lift distribution, and by determining the optimum fuselage lift distribution. An elliptic wing carrying the optimum lift distribution for that plan form is used to demonstrate the possible drag reduction, in some cases from 30% to 40%. It is emphasized, however, that it may not be possible to generate the required fuselage lift distribution without producing excessive vortex drag, and that experiments are necessary to determine how much of the theoretical improvements can actually be achieved in practice.

AEROELASTICITY

ANALYSIS OF SHORT-PERIOD LONGITUDINAL OSCILLATIONS OF AN AIRCRAFT-INTERPRETATION OF FLIGHT TESTS. Appendix I - RESPONSE TO TYPICAL ELEVATOR MANOEUVRES. Appendix II - FILTRATION OF EXPERIMENTAL OSCILLATORY CURVES. Appendix III - DETERMINATION OF FREQUENCY, DAMPING FACTOR, AMPLITUDE RATIOS AND PHASE ANGLES OF EXPERIMENTAL CURVES. Appendix IV - REMARKS ABOUT THE UNIT OF AERODYNAMIC TIME. Appendix V - ALTERNATIVE ANALYSIS WITH ATTITUDE RECORDED INSTEAD OF NORMAL ACCELERATION. ANALOGY WITH THE CASE OF LATERAL OSCILLATIONS. S. Neumark. Gt. Brit., ARC R&M 2940, 1956. 55 pp. 17 refs. BIS, New York, $2.70. Development of a method for analyzing experimental curves obtained in flight when an aircraft is disturbed longitudinally by a suitable elevator input and performs mainly short period oscillations.

SOME FLUTTER TESTS ON SWEPT-BACK WINGS USING GROUND-LAUNCHED ROCKETS. W. G. Molyneux and F. Ruddlesden. Gt. Brit., ARC R&M 2949, 1956. 16 pp. BIS, New York, $0.85. Results of tests on flutter models of untapered wings with 20°, 40°, and 60° sweepback, and up to 1.4 Mach Number. A comparison is made between the measured flutter speeds and the speeds estimated using a flutter speed formula. Modifications are proposed to include a compressibility correction. A comparison is also made between measured flutter speeds and those calculated by using two-dimensional incompressible flow theory. This shows that the calculated speeds are lower than the measured speeds, except in the transonic region, where they are in some cases slightly higher. The calculated flutter frequencies are on the average some 20% higher than the measured values.

AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF DEFORMATION ON THE AERODYNAMIC CHARACTERISTICS OF A SWEPT-BACK WING. Appendix I - THE WEISSINGER METHOD FOR THE PREDICTION OF LOADING DUE TO TWIST ON A SWEPT-BACK WING. Joseph Black. Gt. Brit., ARC R&M 2938, 1956. 34 pp. BIS, New York, $1.62. Evaluation of the effects of structural deformation on the pressure distributions over a tapered wing with 44° leading-edge sweepback, carried out in a wind tunnel at a Reynolds Number of 0.6×10^6. A technique for constructing a model and deforming it into any desired shape is successfully developed. The plastic used for model construction can be deformed to any desired shape at 100° C. From the modes investigated the appropriate deformations required to produce an almost elliptic span loading at a selected moderate overall lift or to delay tip stalling at high incidence, are established. The most important feature is to have a maximum wash-out at about 0.7 semispan with a decrease of wash-out from there to the tip, and not a continuously increasing wash-out right to the tip.

ILL-CONDITIONED FLUTTER EQUATIONS AND THEIR IMPROVEMENT FOR SIMULATOR USE. E. G. Broadbent. Gt. Brit., RAE TN Struc.195, June, 1956. 22 pp. Description of a method for transforming the flutter matrix so as to reduce the inertia couplings between like modes to zero, in order to avoid the ill-conditioning in equations in which simple arbitrary modes are used as coordinates. Includes numerical examples and discussion of the general problem of choosing coordinates in a flutter calculation.

FATIGUE LOADINGS IN FLIGHT LOADS IN THE FUSELAGE AND NOSE UNDERCARRIAGE OF A VARSITY. E. W. Wells. Gt. Brit., RAE TN Struc.193, May, 1956. 19 pp. Tests results tabulated in terms of the number of load ranges of a given magnitude occurring during various ground and flight conditions. An estimate is made of the loads in a typical operational training flight to show the relative importance of the various conditions. A relationship is established between the fuselage loads and the acceleration at the aircraft center of gravity when flying in turbulence; this enables the flight-test results to be linked to operational data obtained on gusts.

MODES AND FREQUENCIES OF WINGS OF TRIANGULAR PLANFORM. J. L. Lubkin and Y. L. Luke. USAF WADC TR 56-335, June 29, 1956. 46 pp. 15 refs. Analysis to determine the lowest frequencies and vibration mode shapes for certain cantilever triangular plates, in order to provide a method for the aeroelastic analysis of delta wings. The Rayleigh-Ritz method is used to refine previous analytical studies for a 45° right triangular plate. Other configurations are studied, including a 45° tapered plate, a uniform 60° plate, and a

45° built-up plate of laminated construction which exhibits a step-wise thickness variation.

SOME FATIGUE CHARACTERISTICS OF A TWO SPAR LIGHT ALLOY STRUCTURE (METEOR 4 TAILPLANE). K. R. Raithby and Jennifer Longson. Gt. Brit., ARC CP 258, 1956. 31 pp. BIS, New York, $0.81. Experimental investigation on 61 configurations treated as representative of small-scale wing systems and tested under a variety of loading conditions, with particular attention given to determining the effects of mean load and alternating load on endurance. Results for different mean loads are in the form of endurance curves, and indicate that, for a given alternating load, the endurance is roughly inversely proportional to the mean load. Data derived from an inquiry into the effects of preloading, periodic overloading, and low temperatures show that both preloading and periodic overloading may substantially improve endurance, which is revealed to be higher at low temperatures than at room temperature.

THE AERODYNAMIC FORCE ON AN AIRFOIL IN A MOVING GUST. J. W. Miles. J. Aero. Sci., Nov., 1956, pp. 1,044-1,050. Calculation, assuming an incompressible flow, of the lift increment due to a sharp edged gust that moves across a two-dimensional airfoil at a relative velocity different from the flight velocity. The lift is determined as a function of dimensionless time parameter (σ) and a relative velocity parameter (λ), when the relative velocity parameter does not equal zero or one. Application of results is made to the problem of a blade-wing interference on a winged helicopter.

LONGITUDINAL RESPONSE OF AIRCRAFT TO OSCILLATORY VERTICAL GUSTS (FREQUENCY ANALYSIS INCLUDING THE EFFECT OF UNSTEADY AERODYNAMICS). J. K. Zbrozek. Gt. Brit., RAE Rep. Aero.2559, Nov., 1955. 55 pp. 17 refs. Both the exact (including unsteady aerodynamics) and the approximate (using the classical approach to dynamic stability) formulas are given for calculations of aircraft having velocity and rate of pitch arising from a sinusoidal gust, and it is shown that, for practical applications, the classical approach should be sufficient. The formula for gust-load frequency function is analyzed, and a simple estimation method to determine this function with good accuracy is described. Includes graphs of frequency function of unsteady lift and downwash to facilitate the numerical computations.

PROBABILITY AND FREQUENCY CHARACTERISTICS OF SOME FLIGHT BUFFET LOADS. Appendix A - SOME CHARACTERISTICS OF A GAUSSIAN RANDOM PROCESS. Appendix B - NUMERICAL FILTERING. W. B. Huston and T. H. Skopinski. US, NACA TN 3733, Aug., 1956. 52 pp. Experimental investigation in the stall and in the shock regime of buffet loads measured on the unswept wing and tail of a fighter airplane. Results indicate that wing-buffeting is essentially a Gaussian random process for a representative stall maneuver and that the buffeting intensity appears to vary linearly with penetration beyond the buffet boundary for a representative pull-up into buffeting in the shock regime. The power spectrum of the wing-root shear shows that buffet-shear loads are primarily associated with response in the first symmetrical bending mode, while the power spectrum of the tail-root shear shows that the tail loads are primarily associated with the fuselage in a torsion or "tail-rocking" mode.

THE SAMPLING ERRORS OF TURBULENCE MEASUREMENTS. Appendix - THE FITTING OF NEGATIVE BINOMIAL DISTRIBUTIONS. N. I. Bullen. Gt. Brit., RAE Rep. Struc.208, May, 1956. 18 pp. 11 refs. Calculation of frequency and magnitude of gusts in the atmosphere obtained from counting accelerometers which are fitted in aircraft and which count automatically the number of accelerations at a given series of magnitudes. Includes derivation of a formula which takes into account the variations in gust density. Results of a comparison indicate that the calculated sampling errors for the 10 ft./sec. gust are approximately four times those calculated on the basis of a random distribution.

AIRPLANE DESIGN

Cockpits

DESIGN, FABRICATION AND TEST OF PANED CANOPY ASSEMBLY. USAF WADC TR 54-394, Jan., 1954. 120 pp. Development of a paned canopy assembly for fighter aircraft duplicating the external contours of the usual bubble type. The design is fabricated and exposed to the standard hot soak, cold soak, ambient pressure, and pressure cycling tests. The canopy lattice is fabricated from orlon fabric laminated with monomeric methacrylic resin. Thermal expansion characteristics of this material closely approximate those of methyl methacrylate sheet.

MATERIALS

THE CHOICE OF MATERIALS FOR AIRFRAMES. K. L. C. Legg. Aircraft Eng., Sept., 1956, pp. 304-312. Review and evaluation of existing materials and those likely to be available in the future, in terms of the technological and production problems to be encountered in advanced aircraft design. Four groups of materials - light alloys, steels, titanium, and plastics - are discussed in the light of their respective strengths and stiffnesses, reactions to heat, fatigue limits, and susceptibility to corrosion and erosion.

Metals & Alloys, Nonferrous

TENSILE PROPERTIES OF INCONEL AND RS-120 TITANIUM-ALLOY SHEET UNDER RAPID-HEATING AND CONSTANT-TEMPERATURE CONDITIONS. G. J. Heimerl, I. M. Kurg, and J. E. Inge. US, NACA TN 3731, July, 1956. 29 pp. Experimental investigation including a comparison of yield and rupture stresses obtained by rapid heating with yield and ultimate stresses from elevated-temperature tensile stress-strain tests for 1/2 -hour exposure. Also includes a determination of the applicability of master curves and

temperature-rate parameters to the prediction of yield and rupture stresses and temperatures under rapid-heating conditions. Results of the rapid-heating tests with Inconel and RS-120 titanium-alloy sheet heated to failure at uniform temperature rates from 0.2° F. to 100° F. per sec. under constant-tensile-load conditions indicate that at such temperature rates yield and rupture stresses may be somewhat less or appreciably greater than the corresponding tensile yield or ultimate stresses obtained from the conventional elevated-temperature tests, and that, in general, yield and rupture temperatures for these materials increase with the logarithm of the temperature rate, with the exception of the titanium alloy at certain stress levels.

Testing

PRELIMINARY INVESTIGATION OF TECHNIQUES AND METHODS FOR PHOTOELASTIC DETERMINATION OF STRESSES IN TRANSPARENT INSTALLATIONS. W. E. Williams. USAF WADC TR 54-496, Aug., 1954. 82 pp. Determination of stress-optical coefficients of various materials used in transparent aircraft installations, in order to determine whether the existence of a purely torsional or bending stress could be predicted by the direction of an abnormal tensional stress in the immediate neighborhood. Also investigated are the effects of cementing and edge attachments.

MATHEMATICS

SUMMATION OF A SLOWLY CONVERGENT FOURIER SERIES OCCURRING IN A FLUID MOTION PROBLEM. G. F. Miller. Proc. Royal Soc. (London), Ser. A, Sept. 25, 1956, pp. 17-27. Description of methods for the evaluation of a slowly convergent sine series $S(\theta)$ $(0 \leq \theta \leq \frac{1}{4}\pi)$ in which the coefficients satisfy a linear recurrence relation; establishment of a connection between $S(\theta)$ and the hypergeometric function; and derivation of a general technique for evaluating an extensive class of power series in a complex variable. This technique is based on the asymptotic expansion of products of the coefficients in descending inverse factorials, and it is applied to $S(\theta)$ in two ways: in the first, use is made of the connection with the hypergeometric function; in the second, the general coefficient in the series is expanded directly by solving the recurrence relation in series. Includes proof of a lemma on the asymptotic expansion of products of gamma functions, which is fundamental in the application of the procedure to hypergeometric series.

ON THE FUNCTIONS OF THE PARABOLIC CYLINDER. D. I. Epstein. NYU Inst. Math. Sci., Div. Electromagn. Res., Res. Rep. BR-19, June, 1956. 24 pp. OSR-sponsored derivation of an additional theorem in parabolic coordinates for the separated solutions of the reduced wave equations, based on the property that the reduced wave equation is invariant under translations and rotations of the coordinate system. Also includes discussion of the problem of expanding any separated one-valued regular solution in terms of the solutions belonging to the basic set. Certain integrals which arise in diffraction problems and involve functions of the parabolic cylinder are evaluated asymptotically for large values of a parameter which is the reciprocal wavelength of the incident electromagnetic field.

OPERATEURS SYMBOLIQUES. Henri Pailloux. France, Min. de l'Air PST 317, 1956. 77 pp. SDIT, 2 Av. Porte-d'Issy, Paris 15, Fr. 880. In French. Modification of the definition of symbolic linear operators to include functions of one or more variables. Application of results to the general solution of differential equations and partial linear derivatives having constant coefficients, with and without the second member. Equations of equilibrium and those of small motions in the elastic media are analyzed; Maxwell equations are taken into account; and the relationship between the operators with n variables and the equations with partial derivatives having n + 1 variables is discussed.

EXTREME VALUE PROPERTIES OF HERMITIAN MATRICES. M. Marcus and B. N. Moyls. U. Brit. Columbia, Dept. Math. AFOSR TN 56-341, Aug., 1956. 36 pp. 21 refs. Analysis relying heavily on some of the properties of the compound of a transformation. Two concavity theorems for the symmetric functions are proved and their applications outlined. The classical Minkowski determinant inequality is extended to all the coefficients in the characteristic polynomial.

ENCLOSED QUANTUM MECHANICAL SYSTEMS. T. E. Hull and R. S. Julius. Can. J. Phys., Sept., 1956, pp. 914-919. 12 refs. ARDC-supported research, including the description of a method which leads to a general asymptotic formula for the eigenvalue problems associated with enclosed quantum mechanical systems. A brief description of these problems and of some attempts to deal with them precedes the derivation of the formula which yields a simple asymptotic approximation to the eigenvalue in each particular case, once the eigenfunction of the corresponding unrestricted system is known.

POWER PLANTS

INDUCTION SYSTEM SELECTION. Appendix - ANALYTICAL COMPARISON OF ISENTROPIC INTERNAL AND EXTERNAL COMPRESSION INLETS. Harry Drell and T. A. Sedgwick. Aero. Eng. Rev., Nov., 1956, pp. 67-75. Examination of various types of induction systems, with results leading to suggestions for selecting the optimum design. Consideration is limited to external- and internal-compression inlets, each available in two- or three-dimensional types. The external - and internal-compression inlets are compared with each other on a thrust basis by computing the ratio of propulsive thrusts of the internal compression inlet installations to those of the corresponding optimum thrust external compression installations at the same free-stream Mach Number and cowl drag correction factor. A similar comparison is made on the basis of specific fuel consumption.

Jet & Turbine

THE EFFECTS OF GEOMETRY AND OTHER PARAMETERS ON THE AIR FLOW PATTERNS IN A VORTEX COMBUSTION CHAMBER. E. C. Roberson. Gt. Brit., NGTE Rep. R.186, June, 1956. 35 pp. 11 refs. Experimental investigation with results indicating that pattern symmetry is improved by using multiple entries; that the onset of secondary flow can be delayed by using steeper flow angles or more uniform velocity profiles in the entering airstream; and that the effect of exhaust configurations on the patterns is negligible, although a large measure of control can be exerted by the use of spiral guide vanes (splittered) attached to flat side walls. Examination of the value of the decay exponent used to modify the free vortex law leads to the recommended value of 1.0 for practical applications.

THE HIGH TEMPERATURE TURBO-JET ENGINE. D. G. Ainley. J. RAeS, Sept., 1956, pp. 563-581; Discussion, pp. 581-589. 38 refs. Discussion of the major problems of high-temperature operation, with particular emphasis on the highly stressed turbine blades which are wholly submerged in the very hot gas stream. Study reviews the applications for high-temperature engines, the problem of blade cooling and some cooling methods, the gas-to-blade heat transfer process, the design of air-cooled blades, the choice of turbine design, and the potentialities of air cooling.

DESIGNING FOR THE AUTOMATIC CONTROL OF TURBOJET ENGINES. A. M. Wright. Aero Dig., Sept., 1956, pp. 28-33. Analysis of a hydraulic-mechanical system used for the control of fuel admission, overspeed, and overtemperature. In the fuel flow control the engine rpm and the compressor inlet air temperature and pressure are measured and fed into the control. The control contains computing mechanisms that solve a set of equations, the fuel flow is then limited to the values permitted by the equations at each set of engine conditions. The corrected speed computer is affected by a change in inlet air temperature or a change in engine speed. The metering-head control maintains the fuel pressure proportional to the inlet air temperature during acceleration. A steady-state speed governor uses a pair of flyweights for controlling fuel flow and thereby maintains a constant speed. A hydraulic amplifier uses a cam to determine the relation between the compressor blade angle and the corrected speed.

ROTATING WING AIRCRAFT

SOME EXAMPLES OF LAMINAR BOUNDARY-LAYER FLOW ON ROTATING BLADES. Nicholas Rott and W. E. Smith. J. Aero. Sci., Nov., 1956, pp. 991-996, 1,006. 12 refs. Application of the Fogarty and Falkner-Skan results to a number of specific examples involving both positive and negative pressure gradients in the chordwise direction. In these examples the chordwise component of flow in the boundary layer is the solution of the two-dimensional problem treated by Falkner and Skan. The spanwise-flow component is determined by a linear partial differential equation involving the chordwise component. This equation is separated into two ordinary differential equations by means of appropriate similarity transformations. Results of a numerical integration indicate how the spanwise component is affected by the chordwise pressure gradient.

SPACE TRAVEL

STATIONARY TRAJECTORIES FOR A HIGH-ALTITUDE ROCKET WITH DROP-AWAY BOOSTER. G. Leitmann. Astronautica Acta, Fasc. 3, 1956, pp. 119-124. Deduction of a solution to the problem of optimum thrust programming for a rocket which is required to reach a given altitude with given pay load (rather than given burnt mass) and minimum fuel expenditure. Analysis takes into account the effect of the rocket dead weight and particular attention is paid to the case of a rocket with disposable booster, in order to determine the necessary conditions for a minimum initial mass.

MEDICAL PROBLEMS INVOLVED IN ORBITAL SPACE FLIGHT. Hubertus Strughold. Jet Propulsion, Sept., 1956, pp. 745-748, 756, 788. 36 refs. Discussion of medical problems involved in circumplanetary or orbital space flight including: the state of weightlessness, its sensomotor effect, and its effect upon the general well-being of satellite-vehicle occupants; the optical properties of the enviroment and the visual appearance of light sources; physiological day-night cycling; and problems of human engineering of the space cabin involving pressurization, supply of oxygen, removal of carbon dioxide, photosynthetic gas exchange, and the event of sudden decompression of the cabin.

STRUCTURES

NOTES ON THE PRACTICAL APPLICATION OF THE METHOD OF R.A.E. REPORT No. STRUCTURES 168. D. Williams. Gt. Brit., RAE Rep. Struc. 209, May, 1956. 49 pp. Applications of a method outlined previously for deriving the influence coefficients of a wing, which in turn are used to obtain the deflection and stresses. Method considers boundary conditions for wings, and includes reactions at a free-corner station, a free-edge station, a re-entrant corner, and a re-entrant corner with a stepped boundary. Also discussed are hinge moments due to ailerons, flaps, and wing-tip fins; connections of wing and fuselage; treatment of oblique stringers and shear webs; wings infinitely stiff in shear, reinforced by oblique stringers; and gaps in skin continuity. An approximate method is given, taking into account shear deflections with oblique shear webs, and an exact method, taking into account oblique stringers and shear webs.

Beams & Columns

EXPERIMENTAL INVESTIGATION OF THE STRENGTH OF MULTIWEB BEAMS WITH CORRUGATED WEBS. A. F. Fraser. US, NACA TN 3801, Oct., 1956. 17 pp. Includes tests on two

types of connections between the web and the skin, and comparison of the structural efficiency of corrugated-web with that of channel-web multiweb beams.

Cylinders & Shells

EQUATIONS OF THE ENGINEER'S NON-LINEAR THEORY OF THIN SHELLS. Zdzisław Parszewski. Arch. Mech. Stosowanej (Warsaw), No. 2, 1956, pp. 143-154. Derivation of equations of equilibrium and compatibility based on the assumptions of the Vlasov's theory of shells.

METODA UTWIERDZENIA SPRĘŻYSTEGO W KONSTRUKCJACH LOTNICZYCH. Zbigniew Brzoska. Inst. Lotnictwa, Prace, No. 2, 1955. 69 pp. In Polish. Description of the elastic-clamping method of solution for highly redundant aircraft structures, its application to the solution of typical structures (box beams with four flanges, panels with three rods), and its extension to cases in which the compensating group is determined by more than one parameter, in order to obtain the solution for stiffened shells having a great number of longitudinal rods. Includes examination of the effect of distortion of bulkheads and consideration of methods for a rapid estimate of the effect of cutouts. The method involves dividing all the internal forces into two groups, one of which equilibrates the external loading, and the second, (compensating group) with the resultant equal to zero, assures the continuity of displacements. Fixed points (nodes) and coefficients of elastic damping are introduced to simplify the calculations.

Elasticity & Plasticity

A MODIFIED INCREMENTAL STRAIN LAW FOR WORK-HARDENING MATERIALS. W. H. Warner and G. H. Handelman. Quart. J. Mech. & Appl. Math., Sept., 1956, pp. 279-293. 13 refs. WADC-supported development of a generalization of the Hodge, Prager, and Drucker incremental strain law to afford the possibility of several different types of loading regions in contrast to a single loading or unloading region of the older theories, and to permit explicit inversion of the stress-strain relations and proof, in the Greenberg manner, of minimum principles for the stress and strain rates. An absolute minimum principle corresponding to the differential equations of structural stability is developed, and a particular evaluation of the coefficients indicates that the new law may have broader applications than the previous theory.

Plates

THE BUCKLING SHEAR STRESS OF SIMPLY-SUPPORTED, INFINITELY-LONG PLATES WITH TRANSVERSE STIFFENERS. P. W. Kleeman. Gt. Brit., ARC R&M 2971, 1956. 18 pp. BIS, New York, $0.90. Theoretical investigation of plates with stiffeners spaced at regular intervals, dividing the plate into a number of panels of uniform size, in order to calculate the stresses for all combinations of the bending and torsional stiffness of the stiffeners. Torsional rigidity of the stiffeners is neglected, the stiffeners are assumed to act along transverse lines in the central plane of the plate, and the calculations are carried out for different values of a third parameter - the ratio of the width of the panel to the stiffener spacing. The analysis is an extension of the Stein-Fralich method, using an energy technique which employs the Lagrangian Multiplier for the imposition of the stiffener restraints. Results are presented in tabular and graphical form.

NAPRĘŻENIA MONTAŻOWE W PŁYTACH. Witold Nowacki. Arch. Mech. Stosowanej (Warsaw) No. 2, 1956, pp. 215-232. In Polish, with summaries in English and Russian. Analysis of the assemblage stresses in plates, considering a plate which has a slight initial curvature, and culminating in a method of solution for a plate simply supported on part of its periphery and rigidly fixed at the remaining part. The problem is reduced to the solution of a system of integral equations. Includes some simple illustrative examples.

Sandwich Structures

A STUDY OF THE EFFICIENCY OF HIGH-STRENGTH, STEEL, CELLULAR-CORE SANDWICH PLATES IN COMPRESSION. A. E. Johnson, Jr., and J. W. Semonian. US, NACA TN 3751, Sept., 1956. 26 pp. 12 refs. Theoretical investigation with results in the form of efficiency curves applicable for determining optimum proportions of sandwich plates for any value of compressive loading intensity. Includes comparison between the efficiency of optimum-proportional steel sandwich plates and solid plates of high-strength steel, and of aluminum and titanium alloys at 80° and 600°F. The curves are presented for sandwich plates of various proportions subjected to compressive end loads for the two temperatures. Analytical results indicate that sandwich plates of optimum design require the use of the minimum core thickness and density necessary to attain approximately the yield stress in the facing sheets at the design value of the structural index.

Thermal Stress

ON THE THERMOELASTIC PROBLEM IN THE CASE OF BODIES OF ANY TYPE OF CURVILINEAR ORTHOTROPY. J. Nowiński, W. Olszak, and W. Urbanowski. Bul. Acad. Polonaise Sci. (Warsaw), No. 2, 1956, pp. 97-104. Application of the analogy of thermal load (as proposed by Duhamel and Neumann) to bodies of any type of curvilinear orthotropy. With this analogy the thermoelastic problem can be reduced to the solution of the isothermal problem of the theory of elasticity for a body loaded with body and surface forces that are equivalent in the elastic sense. Deflections and stresses are obtained for the case of a thin anisotropic wing of circular cross section with axially symmetrical temperature distribution, and for a long cylinder.

THERMAL STRESSES IN AIRPLANE WINGS UNDER CONSTANT HEAT INPUT. F. V. Pohle and Irwin Berman. USAF WADC TN 55-330, July, 1956. 43 pp. 23 refs. Theoretical investigation to extend previous analyses for nonconstant boundary-layer temperature to the treatment of a wide range of geometrical parameters in order to provide results, in the form of graphs for a specific model for which test data are available, that will be practical for design work. The buckling problem and discontinuities at juction points are neglected.

THERMAL BUCKLING OF SUPERSONIC WING PANELS. N. J. Hoff. J. Aero. Sci., Nov., 1956, pp. 1,019-1,028, 1,050. WADC-sponsored theoretical investigation of the temperature and thermal stress distributions in multicellular wing structures in order to establish a buckling criterion for the panels of cover plates subject to thermal stresses. Analysis assumes that the heat input from the air to the cover plate is constant over one cell of the wing and during the period of time considered, and that no resistance to the flow of heat is offered by the connection between the cover plate and the web. In the thermal stress calculations, the shear webs are assumed to be flat plates rigidly connected to the cover plates along their lines of intersection with the thermal stress reduceable by providing nonrigid connections, but the final thermal stress formulas are not valid for wings incorporating such arrangements. In the buckling analysis, the cover plates are assumed to be flat, to have a width L_c, and to be long in the spanwise direction, and a further hypothesis states that conditions change sufficiently slowly from cell to cell so that two or more adjacent cells reach their stability limit at the same time.

THERMAL BUCKLING. F. V. Pohle and Irwin Berman. USAF WADC TN 56-270, May, 1956. 32 pp. 14 refs. Analysis of thermal buckling in order to evaluate several methods for determining a characteristic parameter which occurs in a homogeneous linear differential equation with homogeneous boundary conditions. The example of a simply supported rectangular plate is used to illustrate an exact solution. Approximate solutions are obtained by means of the energy method, of a Fourier series method, and by using Green's function to reformulate the problem in terms of a homogeneous integral equation. Comparison is made for determining the most appropriate of these approximate methods for the solution of thermal buckling of a cylinder.

NAPREZENIA CIEPLNE W POWŁOKACH WALCOWYCH. Witold Nowacki. Arch. Mech. Stosowanej (Warsaw), No. 1, 1956, pp. 69-83. In Polish, with summaries in English and Russian. Calculation of the thermal stresses in a circular cylindrical shell due to the temperature increase which varies linearly across the thickness of the shell. Calculations are made using Maysel's integral relation and Vlasov's theory of shells. Solutions are obtained by using a trigonometric series for a shell simply supported at the edges and for a shell having alternate segments simply supported and built in.

THERMODYNAMICS

PROPERTIES OF GASEOUS AND LIQUID MIXTURES. W. K. Tang. U. Wis. NRL Dept. Chem. TR WIS-OOR-13, Aug. 9, 1956. 200 pp. 48 refs. Tables of pressure-volume-temperature data for binary mixtures of gases and liquids to provide a basis for establishing pseudo-critical constants of mixtures in terms of the critical constants of the separate components, and from such properties to calculate the deviations of various thermodynamic properties from ideal behavior. The data are collected from published literature for 41 binary and two ternary systems, representing 14,000 points from 218 different compositions and 23 compounds.

THERMODYNAMIC CHARTS FOR HIGH TEMPERATURE AIR CALCULATIONS (2,000°K TO 9,000°K). J. G. Logan, Jr. Cornell Aero. Lab. Rep. AD-1052-A-3 (AFOSR TN 56-342), July, 1956. 25 pp. Compilation of thermodynamic charts useful for shock wave and isentropic flow calculations. Each chart contains plots of three different thermodynamic variables in order to perform calculations for constant values of entropy, pressure, density, and enthalpy.

SELECTED COMBUSTION PROBLEMS. II - TRANSPORT PHENOMENA, IGNITION, ALTITUDE BEHAVIOUR AND SCALING OF AEROENGINES. Combustion Colloquium, Liège, Belgium, Dec. 5-9, 1955. NATO, Advisory Group for Aeronautical Research and Development (AGARD). London, Butterworths Scientific Publications; New York, Interscience Publishers, Inc., 1956. 495 pp. 1,022 refs. 90s. $12.50. Contents: Les Performances des Moteurs d'Avions, A. Capette. Fuels for Turbojet Powered Aircraft, R. R. Hibbard and H. C. Barnett. Fundamental Principles of Flammability and Ignition, B. Lewis and G. von Elbe. The Ignition of Flowing Gases, L. D. Wigg. Inflammation et Allumage dans les Moteurs-Fusées à Propergols Liquides, M. Barrère and A. Moutet. Thermal Ignition, with Particular Reference to High Temperatures, R. S. Brokaw. Fundamental Equations in Aerothermochemistry, Th. von Kármán. Quelques Considérations sur la Convection de la Chaleur aux Grandes Vitesses et aux Températures Elevées, E. A. Brun. Sources of Transport Coefficients and Correlations of Thermodynamic and Transport Data, F. Hilsenrath. Combustion en Altitude dans les Turbo-Reácteurs, F. Soissons. The Influence of Altitude Operating Conditions on Combustion Chamber Design, S. L. Bragg and F. B. Holliday. Combustion in the Turbojet Engine, B. Way. Problems of Combustion under Altitude Condition (Treated from Fundamental Viewpoint), H. G. Wolfhard. Similarities in Combustion, a Review, A. E. Weller. Scaling of Gas Turbine Combustion Systems, D. G. Stewart. Recherche du Brûleur Optimum en Ecoulement Air-Kérosène à Grande Vitesse, B. Salmon and H. Vigne. Scaling of Liquid Fuel Rocket Combustion Chambers, C. C. Ross. Considerations on the Problem of Scaling Rocket Motors, L. Crocco.

Combustion

LOW PRESSURE PERFORMANCE OF CYLINDRICAL CAN BURNERS. M. A. Weiss and J. P. Longwell. Jet Propulsion, Sept., 1956, pp. 749-756. Experimental investigation to determine the combustion stability and effeciency of can burners with one, two, and three stages of inlet holes, including tests to determine the effects of varying the number and size of first-stage inlet openings, the diameter and length of the recirculation zone, and changing pressure, mass flow, inlet-jet direction, recirculation-zone wall temperature, and tailpipe length. Results indicate that stability depends primarily on the geometry of the upstream (first) stage of holes and the region inside the can (the recirculation zone) upstream of that stage; size and location of downstream stages are of minor importance to stability but affect overall efficiency. Results of an empirical stability correlation show that the lean and rich blowout limits are functions of can diameter and pressure to the 0.8 power. A can-stability mechanism depending on overall reaction rates in a local zone is suggested.

TURBULENT BURNING VELOCITIES OF NATURAL GAS-AIR FLAMES WITH PIPE-FLOW TURBULENCE. J. K. Richmond, J. M. Singer, E. B. Cook, J. R. Oxendine, Joseph Grumer, and D. S. Burgess. US, Bur. Mines TR 1205 (AFOSR TN 56-238), Apr. 30, 1956. 27 pp. 10 refs. Measurements of burning velocity as function of height in Bunsen flames in order to test existing theories of turbulent burning velocity and to search for flame-generated turbulence. Experiments include flame luminosity measurements, using a newly developed flame radiation photometer in the region of wave length = 4315Å; measurements taken with a pitot tube of the direction and magnitude of approach flow at each point, with velocities extrapolated systematically to the mean flame position; determination of the flame turbulence intensity using an electronic probe; computation of burning velocity values by the angle and frustum methods and correlation with the flame-turbulence data; and corrections of cylindrical curvature of the flame to find the true radial distribution of hight. Some technical improvements are presented.

Heat Transfer

HEAT CONDUCTIVITY IN POLYATOMIC, ELECTRONICALLY EXCITED, OR CHEMICALLY REACTING MIXTURES. III. J. O. Hirschfelder. U. Wis. NRL Dept. Chem. Rep. CM 880, Aug. 15, 1956. 40 pp. 13 refs. Survey of theoretical problems involved in estimating the heat conductivity of a chemically reacting gas or gas mixture. Results show the following: (1) the larger the value of the entropy change in a chemical reaction, the greater the value of the specific heat of the reacting mixture and the coefficient of thermal conductivity of the reacting gas mixture; (2) the deviation of the chemical composition from the local equilibrium solution is expressed in terms of higher temperature derivatives which results in non-Fourier heat conductivity; (3) the large Prandtl Numbers of simple gases at low temperature and polar gases at room temperature is supposed to be due to the distortion of the molecular distribution as the result of rotational-translational interactions; (4) although the Prandtl Number of different substances is the same value to within a few percent, the Prandtl Number for mixtures may be twice as large or one-half as small as the Prandtl Number of its components.

VTOL & STOL

TRANSITION-FLIGHT TESTS OF A MODEL OF A LOW-WING TRANSPORT VERTICAL-TAKE-OFF AIRPLANE WITH TILTING WING AND PROPELLERS. P. M. Lovell, Jr., and L. P. Parlett. US, NACA TN 3745, Sept., 1956. 30 pp. Investigation of the stability and control of a remotely controlled model during the transition from hovering to normal flight. The wing of the model can be rotated to 90° incidence during flight so that the propeller thrust axes are vertical for hovering flight. With the wing pivoted at the 30% mean-aerodynamic-chord (MAC) location, successful transition flights could be made when the center of gravity is at the most forward position at which the model could be flown in hovering flight, but uncontrollable pitch-ups occur when the center of gravity is behind this position. With the wing pivoted at the 15% MAC location, successful transition flights could be made when the center of gravity is located anywhere in the forward half of the range of positions that could be trimmed in hovering flight. Therefore, the model has an allowable center-of-gravity range of 8% MAC. Lateral stability and control characteristics are considered generally satisfactory even though, for certain conditions of airspeed and fuselage attitude, the Dutch roll oscillation is lightly damped.

WATER-BORNE AIRCRAFT

THE FULL-SCALE HYDRODYNAMIC PERFORMANCE OF A LARGE FOUR-ENGINED FLYING BOAT AT OVERLOAD IN CALM WATER AND SWELL. J. A. Hamilton and R. V. Gigg. Gt. Brit., ARC R&M 2898, 1956. 38 pp. BIS, New York, $1.89. Investigation using a Solent flying boat in sheltered water and in open-sea swells of heights up to five feet. Results show that flying-boat hulls of similar form to the Solent will porpoise if taken off or landed into swells having lengths greater than the length of the hull, and heights greater than 1-1.5 feet. This applies even if the hull is stable in sheltered water. Swell height and variations in weight do not affect swell stability appreciably. Wind strength reduces swell porpoising considerably, if the take-off is made into swell and wind, but take-offs may be made parallel to the swell crests without the occurrence of any instability. It is concluded that the most desirable design features for swell performance are as follows: (a) adequate lateral and directional stability and control at low speeds, (b) ample acceleration in the initial stages of planing, and (c) adequate hydrodynamic damping in pitch.

WIND TUNNELS & RESEARCH FACILITIES

7th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Ottawa, June, 1955. Publ. in Paris; Wash., Distrib. in US by NACA, 1956. 331 pp. 188 refs. Contents: The Representation of Engine Airflow in Wind Tunnel Model Testing, J. Seddon and L. F. Nicholson. The Influence of Turbojet Airflow on the Aerodynamic Design of Airplanes, Harold Luskin and Harold Klein. The Simulation of the Effects of Internal Flow in Wind Tunnel Model Tests of Turbojet Powered Aircraft, A. J. Evans Boundary Layers on Swept Wing; Their Effects and Their Measurement, D. Küchemann. The Use of Pitot Tubes in the Measurement of Laminar Boundary Layers in Supersonic Flow, R. J. Monaghan. Méthode de Calcul de la Couche Limite Tridimensionnelle; Application à un Corps Fuselé Incliné sur le Vent, E. A. Eichelbrenner and A. Oudart. A Brief Review of Three-Dimensional Boundary-Layer Flows, W. R. Sears. The Simulation and Measurement of Aerodynamic Heating at Supersonic and Hypersonic Mach Numbers, J. R. Stalder and Alvin Seiff. The Status of Heat Transfer and Friction Investigations at Supersonic Speeds, H. H. Kurzweg. The N.R.C. Icing Wind Tunnels and Some of Their Problems, C. K. Rush. Wind Tunnel Simulation of Atmospheric Icing Conditions, C. K. Rush and R. L. Wardlaw. The Fluid Flow Associated with the Impact of Liquid Drops with Solid Surfaces, P. Savic and G. T. Boult. The Icing Problem - Current Status of N.A.C.A. Techniques and Research, U.H. von Glahn. Review of the problems of engine airflow representation in wind tunnel models; brief description of methods used satisfactorily in low subsonic tunnels and of special difficulties associated with testing at transonic speeds; and discussion of techniques of special application to small supersonic tunnels.

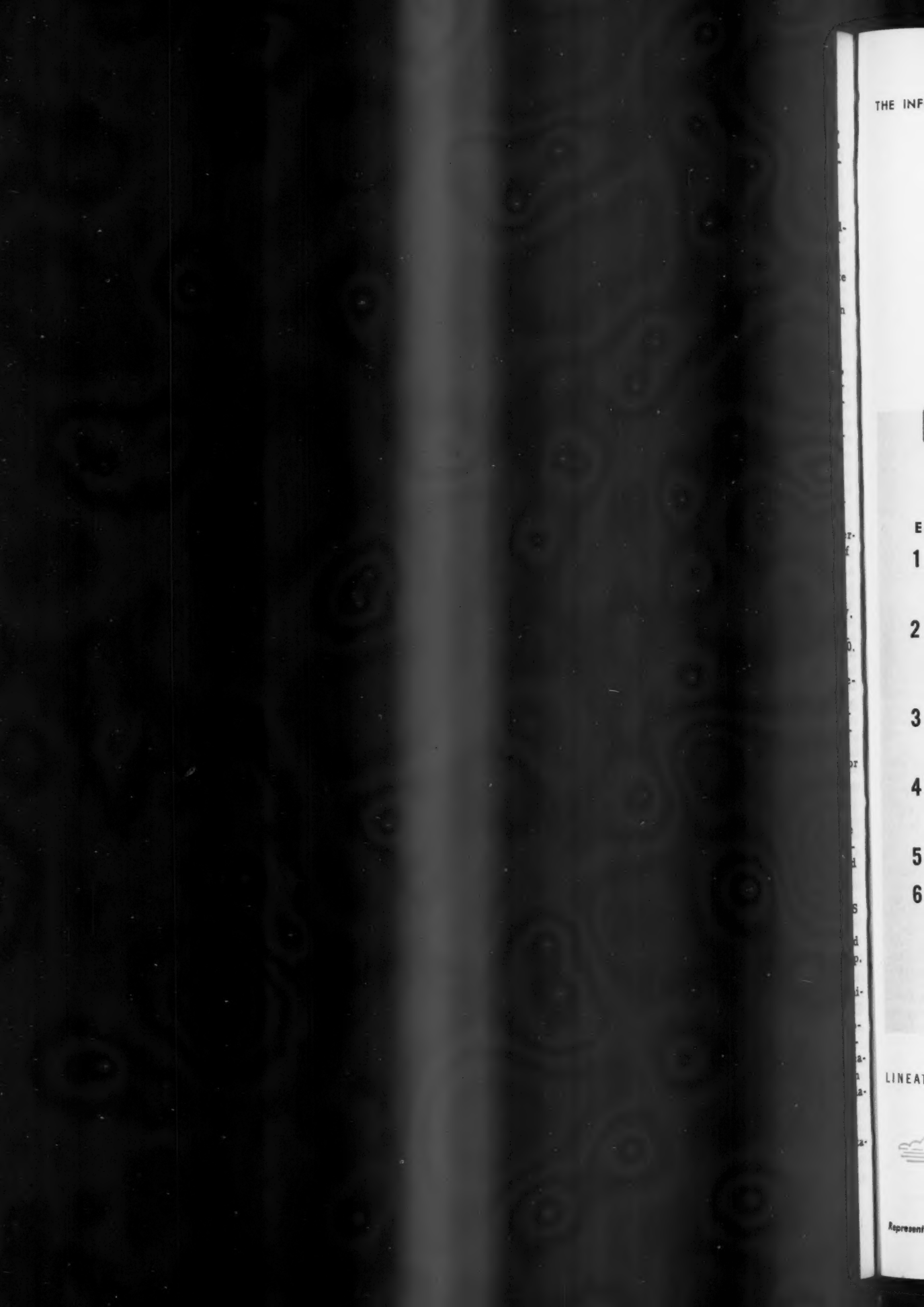
NOTE ON THE NILSON METHOD OF VARIABLE SUPERSONIC WIND TUNNEL DESIGN. M. M. Callan. Canada, NAE LR-174, May 15, 1956. 58 pp. Method of designing a supersonic wind tunnel by prescribing the velocity distribution along the axis from the throat to the point where the desired Mach Number is reached. From this the tunnel contour from the throat to its point of intersection with the zero characteristic is derived. The calculation of the zero characteristic is used to compute the remainder of the nozzle by the method of characteristics. A coordinate system using ξ and η is employed, which represent respectively equipotential lines and streamlines. The partial differential equations of the system are solved by expressing the desired quantities as power series in η with coefficients which are functions of ξ, and which are also related to the prescribed velocity distribution along the axis. Certain tests for the basic function used in the development are also suggested.

PRECISION PLANNING TECHNIQUES AS APPLIED TO THE MANUFACTURE OF SUPERSONIC WIND TUNNEL MODELS. G. W. Rawlings. Gt. Brit., RAE TN A.D.W.2, Feb., 1956. 20 pp. Methods used in the construction of wind tunnel models, taking into account that the model is designed as to external form without compromise for manufacturing convenience, and that the model must conform to exacting limits of accuracy. The model types fall into three classes, airfoil research models, complete aircraft models, and guided missile models. In the airfoil research class the models may be either in the form of a single wing arranged for side or base mounting, or in the form of a complete aircraft mounted upon a mandrel adaptor or sting. The tangent plane generation of solids of revolution and special tools and jigs are emphasized.

BALANCES DARDS A 6 COMPOSANTES. M. Devacht. La Recherche Aéronautique, July-Aug., 1956, pp. 21-31. In French. Application of extensometric wire gages and of Wheatstone bridge installations to systematic analysis permitting the design of aerodynamic balances where the interactions are reduced to a small value. The stability of the installation permits wind-tunnel measurements with a total deformation of $2.10^{-5}\ \frac{\Delta \ell}{\ell}$. The developed methods are applicable to all measurements where gages can be used. The described technique permits automatic correction of the interactions, as well as a considerable augmentation of balance rigidity, particularly useful for transonic and supersonic research.

CONTROL TESTING IN WIND TUNNELS. L.W. Bryant and H. C. Garner. Gt. Brit., ARC R&M 2881, 1956. 56 pp. 29 refs. BIS, New York, $2.70. Methods for the analysis and correction of wind-tunnel effects in order to permit accurate interpretation of results. Formulas are given for tunnel-wall and Reynolds Number effects in both two- and three-dimensional cases. These formulas include blockage, incidence, and residual corrections to measured coefficients, and scale effects for incidence derivatives, small lifts, derivatives of flap angle, and high lifts. The numerical significance of the corrections for wind-tunnel interference and for scale effects is discussed, and in the case of control derivatives it is clear that corrections for scale effect are often more important and should be estimated as part of the program.

MEASUREMENT OF WALL SHEARING STRESS IN THE BOUNDARY LAYER BY MEANS OF AN EVAPORATING LIQUID FILM. J. S. Murphy and A. M. O. Smith. J. Appl. Phys., Sept., 1956, pp. 1,097-1,103. Presentation of a method for the measurement of local wall shearing stress in laminar and turbulent flows. A thin film of suitable fluid is coated on the model surface and the evaporation rate determined from film thickness measurements using light interference fringes. Application of the method to wall stress measurements in flat plate flow is presented and shows good correlation with theory. The technique may be used for determining the shear stress distribution over a surface relative to the value at some reference station. The absolute magnitude of the shear stress at the reference station must be found by another method.



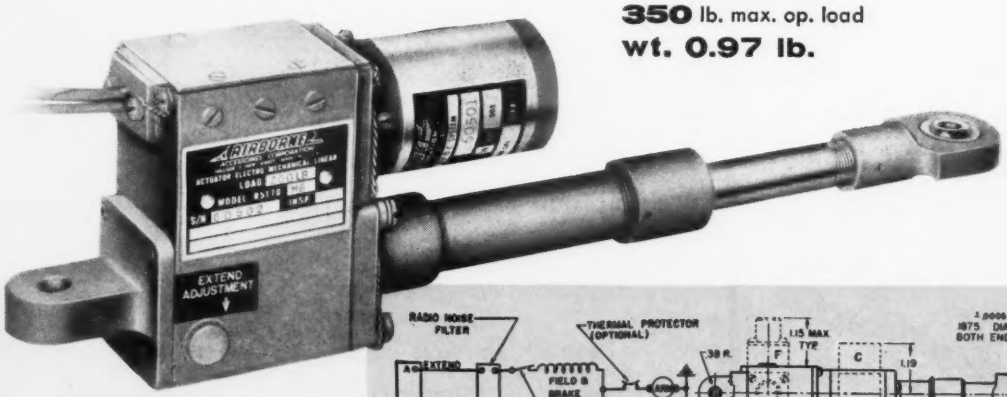
THE INFORMATION ON THIS PAGE IS TYPICAL OF THE DATA YOU WILL FIND IN THE NEW AIRBORNE CATALOG

LINEAR ACTUATOR

R-5170

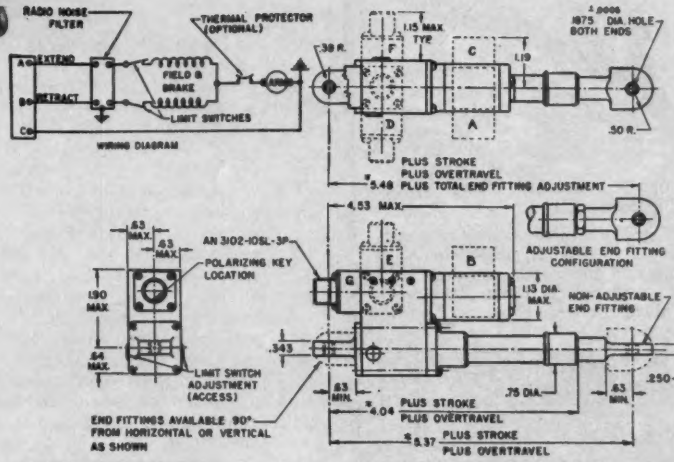
350 lb. max. op. load

wt. 0.97 lb.

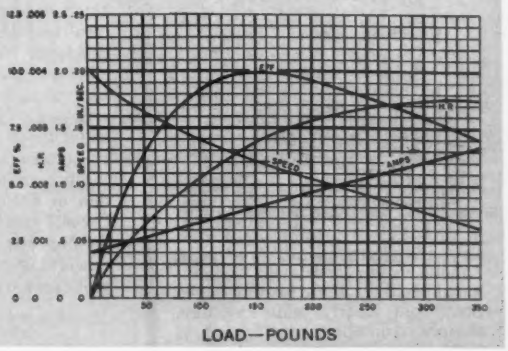


GENERAL ENGINEERING DATA:

1. 26 volt dc split field, series wound reversible, intermittent duty motor with magnetic brake. Available with thermal overload protector.
2. Unit includes limit switches externally adjustable through entire length of stroke, positive overtravel stops, overload clutch, and anti-rotation device.
3. Maximum operating load—350 lb. Ultimate static load—1000 lb. for 12 inches maximum extended length.
4. Weight 0.97 lb. Plus 0.03 lb. x stroke in inches. Plus 0.04 lb. for thermal overload protector.
5. Maximum dimensional tolerance ±.03 in. unless otherwise specified.
6. Dimensions given are minimum lengths for zero stroke. To determine minimum length for required stroke, add stroke plus stroke overtravel plus total end fitting adjustment.



OPTIONAL LOCATIONS	
THERMAL PROTECTOR	CONNECTOR
A	D
B	E
C	F
	G



TYPICAL PERFORMANCE 26 v dc

LINEATOR® • ROTORAC® • TRIM TROL® • ROTORETTE® • ANGLGEAR • ROTOLOK

AIRBORNE®

AIRBORNE ACCESSORIES CORPORATION

HILLSIDE 5, NEW JERSEY

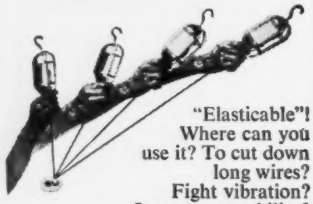
Represented in Canada by: WINNETT BOYD LIMITED • 745 Mt. Pleasant Rd., Toronto 12, Ont.

NEW AIRBORNE CATALOG

Contains full information on the Airborne line of electro-mechanical actuators, feel systems, and electric motors. Write us for your free copy today.

M E I
DESIGN IDEAS

NEW!
ELECTRIC CABLE
ELASTICABLE®
STRETCHES OVER TWICE ITS LENGTH!
CARRIES 2 AMPS!

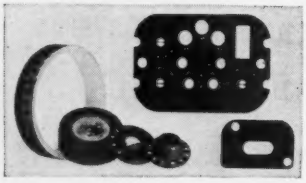


"Elasticable"! Where can you use it? To cut down long wires? Fight vibration? Increase portability? Improve mobility? Save space? Eliminate coils?

21 strand braided conductor. Available 1 to 6 leads, terminated with alligator clips, jacks, spades. 1000 V. insulation between conductors. Choice of covering.

UC UNITED CABLE DIVISION

NEW!
Read "FLUSH-LETTER" panels from *wider* angle. No crevices to collect dirt.



For instruments and controls. Unique *shaved-flush* letters on laminated plastic increase reading angle. Stand out clearly white by day, sharply red when edge-lighted at night. Flush-letter panels keep clean, are impervious to abrasion, water, temperature and vibration. Panels, knobs, dials, switch assemblies, available to your specifications.

UNIVERSAL AVIATION DIVISION

MUTUAL ELECTRONIC INDUSTRIES
CORPORATION
85 Beechwood Avenue, New Rochelle, N. Y.

Hydraulic & Pneumatic

Buckling Loads of Pin-Ended Fluid Columns. M. J. Forray. *J. Aero. Sci.*, Oct., 1956, pp. 972, 973. Design curves for the buckling load in fluid columns, applicable to hydraulic equipment design.

Flight Testing

Flight Techniques for Determining Airplane Drag at High Mach Numbers. De E. Beeler, Donald R. Bellman, and Edwin J. Saltzman. *U. S., NACA TN 3821*, Aug., 1956. 40 pp. 23 refs. Investigation of the stabilized-flight, energy, and accelerometer methods.

Flight Loads During Combat Training. Queenie Baum. *Aircraft Eng.*, Aug., 1956, pp. 262–264. Experimental determination using *V-g* recorders on maneuvers in Mustang aircraft of the RAAF.

Fuels & Lubricants

Determination of Dissolved Oxygen in Hydrocarbons. Anderson B. McKeown and R. R. Hibbard. *Anal. Chem.*, Sept., 1956, pp. 1,490–1,492. 18 refs. Description of a method for the determination of dissolved oxygen in hydrocarbons by a modified Winkler procedure.

Properties of Aircraft Fuels. Henry C. Barnett and Robert R. Hibbard. *U.S., NACA TN 3276*, Aug., 1956. 152 pp. 80 refs. Review and collection of available fuel data useful to the fuel-system designer which shows clearly the range of variation in fuel properties to be considered in fuel-system problems.

Determination of Silicon in Organo-Silicon Compounds. Z. Sir and R. Komers. (*Chem. Listy*, vol. 50, 1956, pp. 88–93.) *Gt. Brit., RAE Lib. Transl. 578*, May, 1956. 8 pp. 26 refs. Description of methods for determining silicon in organo-silicon compounds. The compound is wet mineralized, and the silica thus produced is determined by acidimetry.

Grease Analysis. *Lubrication*, Jan., 1956, pp. 1–12. Description of laboratory tests used to determine lubricating properties of grease. Such tests take into account type of lubricant, composition, and the application involved.

Observations on the Irregular Reaction of Solid Propellant Charges. Leon Green, Jr. *Jet Propulsion*, Aug., 1956, pp. 655–659. 18 refs. Review of studies concerning reaction irregularities in solid-propellant rocket motors.

Gliders

Technical Aspects at St. Yan, 1956. Peter Brooks. *The Aeroplane*, Aug. 3, 1956, pp. 157–161. Description of design and performance characteristics of gliders used in the world championship meet.

Instruments

A Saturable Inductor Magnetometer. A. Wilson. *Gt. Brit., RAE TN TD 6*, Apr., 1956. 12 pp. Description of an instrument developed to measure the attitude of a missile relative to the earth's magnetic field.

Centrale de Mesures Aérodynamiques Vitesses, Nombre de Mach, Températures. G. Dion. *Tech. et Sci. Aéronautiques*, No. 3, 1956, pp. 118–12[illegible]. In French. Description of apparatus used (piloting or navigational purposes) for transmitting measured data for various recordings, automatic control, and target tracking. The device can be applied to servo-measurements including aerodynamic velocity, true speed, Mach Number, temperature, and altitude up to 90,000 ft.

Automatic Control

Servo Amplifiers Use Power Transistors. Bruce M. Benton. *Electronics*, Sept., 1956, pp. 153–155. Description of a servoamplifier system for minimizing the internal temperature rise (above ambient) of semiconductors used in air-borne control equipment.

Some Design Considerations for a Hydraulic Servo. J. M. Nightingale. *Aircraft Eng.*, Aug., 1956, pp. 254–258. Discussion of a particular type of servo with a two-stage control valve having a flapper-nozzle valve as its first stage.

Klystron Control System. III—Specimen Design for A.F.C.; Frequency-Control Loop as a Sampling Servo. R. J. D. Reeves. *Wireless Engr.*, Aug., 1956, pp. 184–189.

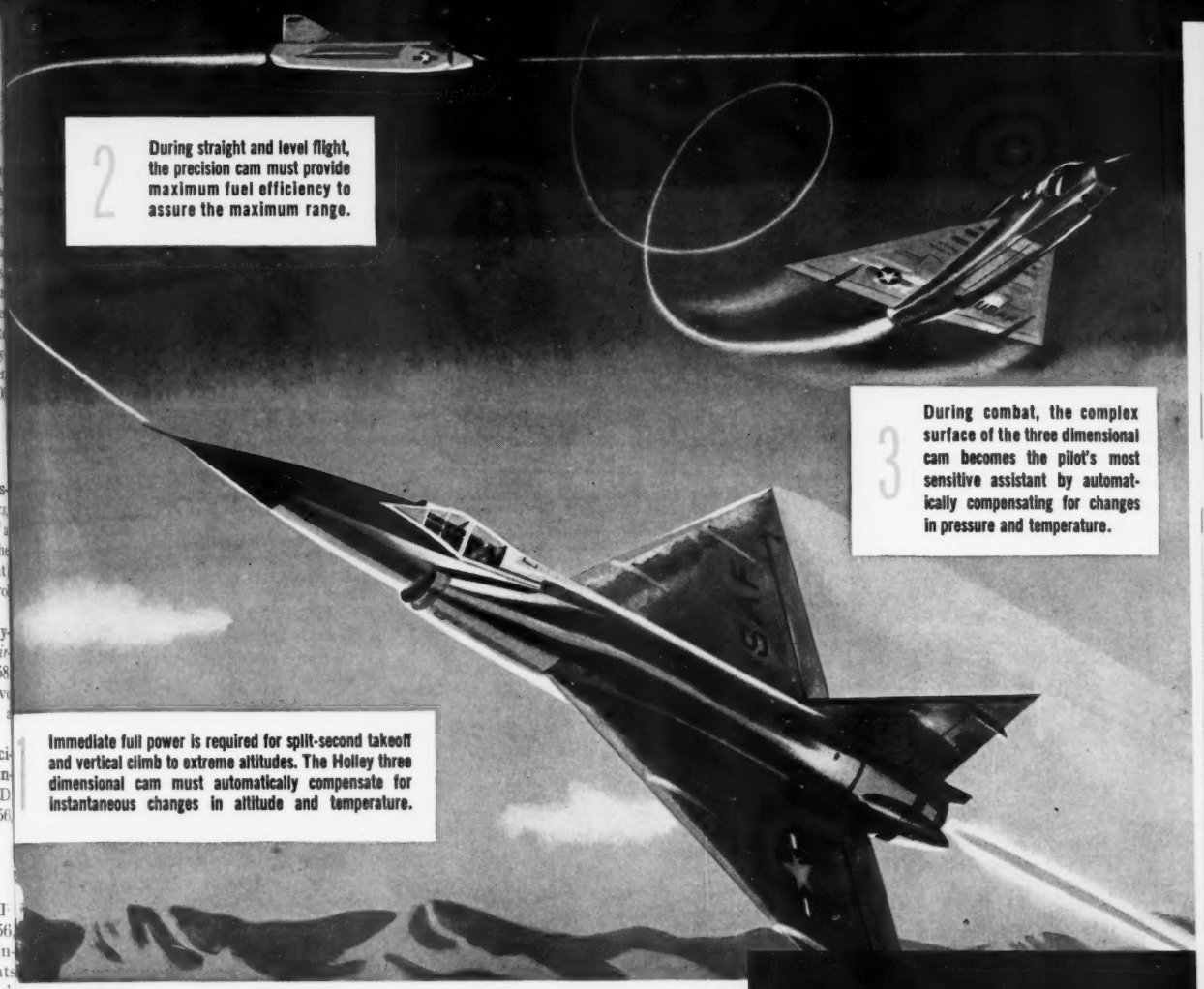
Flight Instruments

The Smiths Flight System. R. F. Gillman. *The Aeroplane*, Aug. 17, 1956, pp. 218–222. Discussion of cockpit instruments for an ILS. These instruments include a direction horizon which simultaneously displays a continuous indication of bank angle and augments this with conventional attitude information and a monitoring display. The system also includes a beam compass which provides heading information with director signals, and a selector which is the primary control of the system.

Flow Measuring Devices

Dynamics of Liquid Flow Control. Allan R. Catheron and Bruce D. Hainsworth. (*Ind. & Eng. Chem.*, June, 1956, p. 1,042.) *Instruments & Automation*, Aug., 1956, pp. 1,525–1,527. Study of the differential pressure transmitter, pneumatic transmission lines, controller, and pneumatic valve leading to the development of a dry differential-pressure transmitter with a deliberately limited dynamic response, a device for reducing the time lags introduced by pneumatic transmission lines, a "universal" liquid flow controller, and a measurement of the improvement on control afforded by the use of volume relays to minimize the time lag induced by the valve actuator.

Probe Measurements in Three-Dimensional Flow. F. A. L. Winternitz. *Aircraft Eng.*, Aug., 1956, pp. 273 278. 20 refs. Survey of instruments and methods used to measure total and static pressure and direction, with comparative tests in a towing tank of two designs of five-orifice pitot-type probes with different head shapes.

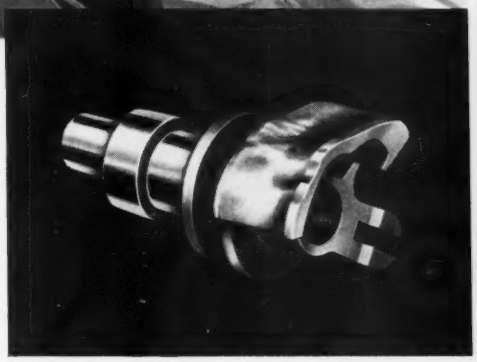

2 During straight and level flight, the precision cam must provide maximum fuel efficiency to assure the maximum range.
3 During combat, the complex surface of the three dimensional cam becomes the pilot's most sensitive assistant by automatically compensating for changes in pressure and temperature.
1 Immediate full power is required for split-second takeoff and vertical climb to extreme altitudes. The Holley three dimensional cam must automatically compensate for instantaneous changes in altitude and temperature.

How the Holley three dimensional cam functions as an automatic co-pilot

The job of the Holley Power Control for jet aircraft is to sensitively control engine power according to the pilot's requirements and, at the same time, make automatic adjustments for split-second variations in altitude, pressure and temperature. The "brain center" of advanced Holley controls is a three dimensional cam which is so contoured that it can adapt itself to all combinations of atmospheric temperature and pressure, from Thule to the Equator and from sea level to extreme altitudes.

In addition to the automatic compensations made for the pilot by the three dimensional cam, it interprets the pilot's request for changes in power. It's the most important link between cockpit and engine.

The three dimensional cam, like the power control itself, is designed, engineered and manufactured by Holley—one of the world's foremost power control manufacturers.



Typical "brain center" of a Holley aircraft engine control. Note the delicate machined surfaces. Each plays a vital role in mechanically regulating the engine under varying conditions.

HOLLEY Carburetor Co.

11955 E. Nine Mile Road • Van Dyke, Michigan

LEADER IN THE DESIGN, DEVELOPMENT, AND MANUFACTURE OF AVIATION FUEL METERING DEVICES

A-23

The Behavior of Transverse Cylindrical and Forward Facing Total Pressure Probes in Transverse Total Pressure Gradients. J. L. Livesey. *J. Aero. Sci.*, Oct., 1956, pp. 949–955.

Pressure Measuring Devices

High-Pressure Standards. *U.S., NBS Sum. TR 2024*, Aug., 1956. 19 pp. Discussion of the NBS developmental program in instruments and standards permitting more accurate measurement of pressures up to 200,000 psi and higher, by: constructing piston gages for absolute measurements in this pressure range, determining a series of fixed points on the pressure scale, establishing standards for calibration of dynamic pressure measuring instruments, investigating the properties of working pressure gages such as those utilizing changes in electrical resistance with pressure, and designing and building mercury columns to serve as primary standards and to measure differential pressures of several atmospheres at total pressures up to 30,000 psi.

A New Technique for Automatic Pressure Data Recording in Final Form. William E. Parker and J. C. Pemberton. *Boeing, Paper*, July 20, 1956. 8 pp. Development of a pressure scanning valve, which accomplishes the readout of 48 unknown pressures with one integral transducer by connecting it sequentially to the pressures, thus requiring only one calibration and one zero circuit.

Un Manomètre Différentiel Miniature. Marc Bassière. *Tech. et Sci. Aéronautiques*, No. 3, 1956, pp. 147, 148. In French. Description of a miniature differential pressure gage for flight and wind-tunnel measurements.

Tachometers

Potentiometer Tachometer has High Sensitivity. Gareth M. Davidson and Melvin Pavalow. *Electronics*, Sept., 1956, pp. 158–161. Description of an electromechanical device which is capable of measuring rotational speeds as low as 1/2,000 r.p.m. and provides a continuous indication of both speed and direction of rotation.

Temperature Measuring Devices

A Self-Balancing Line-Reversal Pyrometer. Donald Buchele. *U.S., NACA TN 3656*, Aug., 1956. 68 pp. 12 refs. Description of an instrument for measuring gas temperatures from 2,900° to 4,500°R.

Resistance Thermometer for Heat Transfer Measurement in a Shock Tube. J. Rabinowicz, M. E. Jessey, and C. A. Bartsch. *GALCIT Memo. 33*, July 2, 1956. 33 pp. 10 refs. Development of a resistance thermometer for measuring surface temperatures and heat-transfer rates under highly transient conditions.

Adiabatic Specific Heat Calorimeter for the Temperature Range 4 to 15°K. M. H. Aven, R. S. Craig, and W. E. Wallace. *Rev. Sci. Instr.*, Aug., 1956, pp. 623–628. 11 refs. Description of a device bridging the interval between liquid helium and liquid hydrogen temperatures.

The Correction of Hot-Wire Readings in a Boundary Layer for Proximity to the Solid Boundary. E. G. Richardson. *J. Aero. Sci.*, Oct., 1956, pp. 970, 971.

Vibration Measuring Devices

Frequency Response of Second-Order Systems with Combined Coulomb and Viscous Damping. Thomas A. Perls and Emile S. Sherrard. *J. Res.*, July, 1956, pp. 45–65. ARDC-ONR-sponsored extension of Den Hartog's results to larger values of viscous friction and larger ranges of frequencies applicable to the evaluation of data obtained by using such inertial instruments as accelerometers and jerkmeters. Results, in the form of curves determined through the use of an analog computer, extend from zero to twice resonance frequency and are presented for easy application to vibration instruments used below their resonance frequency.

Machine Elements

The Wear of Metals under Unlubricated Conditions. J. F. Archard and W. Hirst. *Proc. Royal Soc. (London), Ser. A*, Aug. 2, 1956, pp. 397–410. 20 refs. Experimental investigation using loads of 50 gm. to 10 kg. and speeds of 2 to 660 cm./sec. Two contrasting mechanisms of wear are observed as a broad classification, and the results of nearly all the tests—for all types of mechanisms—indicate that once equilibrium surface conditions are established the wear rate is independent of the apparent area of contact.

Cams Without Masters. Robert C. Sims. *Tool Engr.*, Sept., 1956, pp. 85–89. Description of a tape-controlled cam-milling system used to produce three-dimensional cams for an automatic fuel-flow control system in jet aircraft.

Fastenings

New Class 5 Interference-Fit Thread for Studs, Bolts and Screws. William G. Waltermire. *Mach. Des.*, Sept. 6, 1956, pp. 83–96.

Miniature Screws; A Report on Two New Standards for Threads and Fasteners. E. W. Drescher. *Mach. Des.*, Aug. 23, 1956, pp. 139–144.

Self-Sealing Fasteners. David P. Wagner. *Mach. Des.*, Aug. 23, 1956, pp. 145–148. Discussion giving typical applications of plastic or rubber compounds used as sealers with fasteners.

Design Guide—Industrial Fasteners. Julius Soled. *Mach. Des.*, Aug. 23, 1956, pp. 105–137. Classified guide presenting information on fasteners in the following basic categories: inserts, nuts, pins, retaining rings, rivets, screws, bolts, studs, and washers. Includes the basic forms, design features, materials, size ranges, and sources.

Materials

A Dictionary of Metallurgy. XLVI—*St–Ta*. A. D. Merriman and J. S. Bowden. *Metal Treatment*, Aug., 1956, pp. 315–322.

Corrosion & Protective Coatings

The Fretting Corrosion of Mild Steel. J. S. Halliday and W. Hirst. *Proc. Royal Soc. (London), Ser. A*, Aug. 2, 1956, pp. 411–425. Quantitative investigation including measurements of the frictional forces, the degree of damage and the variations in the electrical contact resistance for a wide range of applied loads, vibration amplitudes and number of cycles of motion, as well as examination, by means of optical and electron microscopy and electron diffraction, of the nature of fretting corrosion scars and debris.

Metals & Alloys

X-Ray Studies of Stresses in Metals; New Explanation of Residual Strain Balancing. *Tech. News Bul.*, Aug., 1956, pp. 105–107. Investigation of changes in the lattice spacing of crystals in a metal, with results indicating that the magnitude and direction of the principal stresses can be computed for a certain loading condition through the use of X-ray, even though the elastic limit has been exceeded.

Effects of Intermittent Versus Continuous Heating Upon the Tensile Properties of 2024-T4, 6061-T6 and 7075-T6 Alloys. G. W. Stickley and H. L. Anderson. *U.S., NACA TM 1419*, Aug., 1956. 7 pp. Description of tests, the results of which indicate that the effects of intermittent heating are cumulative and are the same as for continuous heating at both elevated and room temperature after heating. Includes specific effects of heating at 300°F. and 400°F. for 200 hours on each of the alloys.

Combined Stress Creep Fracture of a Commercial Copper at 250 Deg. Cent. I. A. E. Johnson, J. Henderson, and V. D. Mathur. *The Engr.*, Aug. 24, 1956, pp. 261–265. Results of 15 combined tension and torsion, pure tension, pure torsion and pure comparison creep tests on copper.

Metallurgical Designing for Strength. C. Zener. *Westinghouse Engr.*, Sept., 1956, pp. 146–151. Discussion of atomic structure and deformation in metals in order to show the basic principles and underlying concepts for design considerations.

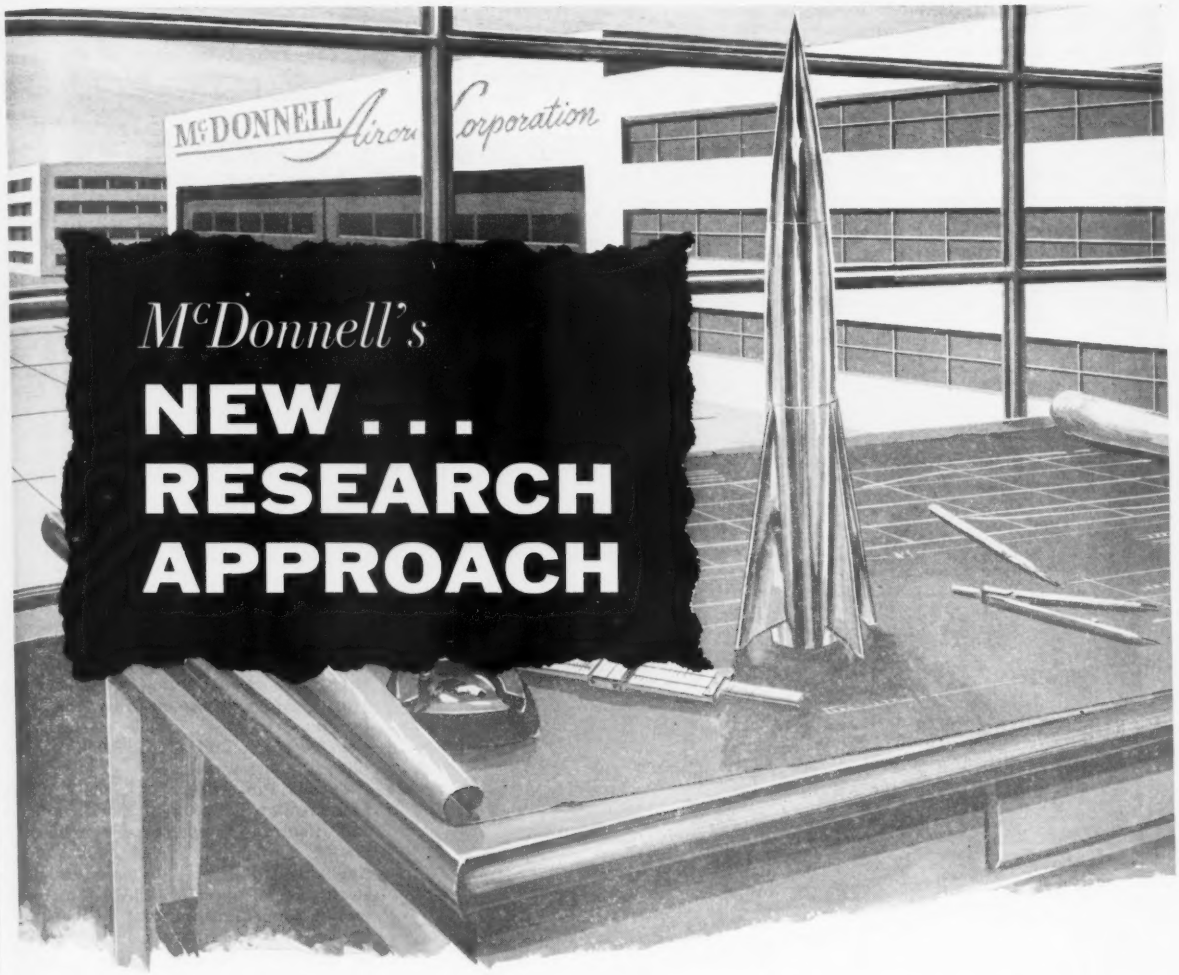
Some Creep Properties of an 18/8 Stainless Steel at Room Temperature, 250°C., 400°C. and 550°C. L. W. Larke and R. A. Whittaker. *Gt. Brit., RAE TN Met. 240*, Mar., 1956. 14 pp.

The Effect of Vibrations on the Mechanical Properties of H. R. Crown Max and Nimonic C. 75. Jerzy Jagaciak and Josiah W. Jones. *Coll. of Aeronautics, Cranfield, Rep. 91*, Sept., 1955. 42 pp. 15 refs.

Materiale Rezistente la Temperaturi Inalte Utilizate în Aviație. I. Guttman. *Rev. Transp.*, Feb., 1956, pp. 74–82. In Rumanian. High-temperature resisting materials; applications.

Probleme bei der praktischen Einführung neuer Hochtemperaturwerkstoffe. F. Kölbl. *Luftfahrttechnik*, Aug. 15, 1955, pp. 63–65. In German. Discussion of problems encountered in materials for use at high temperatures.

Influence of Hot-Working Conditions on High-Temperature Properties of a Heat-Resistant Alloy. Appendix—**Processing of Low-Carbon N-155 7/8-Inch Broken-Corner Square Bar Stock from Heat A-1726.** John F. Ewing and J. W. Freeman. *U.S., NACA TN 3727*, Aug.,



McDonnell Aircraft Corporation has recently organized a new Research Department which will be directed by Dr. Albert E. Lombard, Jr. By this action our management has again evidenced its determination that McDonnell shall maintain its position of leadership in the development of advanced aircraft and weapon systems in future years.

This highly talented research group will be concerned with problems of scientific research directed towards specific objectives in the field of transonic, supersonic and hypersonic aerodynamics, aircraft materials and structures, guidance, control and dynamics of flight, unconventional take-offs and landings, unconventional propulsion, high temperature phenomena and high altitude phenomena, radio propagation and antennas. Additional efforts in the area of systems research will be directed towards conceiving and evaluating the feasibility of new advanced aircraft and weapon systems, establishing time scales for their accomplishment, estimates of probable markets and defining the requirements for additional research done by or sponsored by McDonnell.

Engineers and scientists with advanced education and experience in defining, executing or overseeing research projects related to aircraft, are invited to investigate career opportunities as a member of our new research staff. Write in confidence, including a detailed experience resume to:

RAYMOND F. KALETTA
Technical Placement Supervisor
Box 516 • St. Louis 3, Missouri

McDONNELL Aircraft Corporation

1956. 134 pp. Experimental investigation with results serving to explain many of the observed variations in properties for the hot-worked condition.

Werkstoffe für feuerberührte Bauteile in Strahltriebwerken. O. Lutz and W. Lohse. *Luftfahrttechnik*, Nov. 15, 1955, pp. 118–123. In German. Investigation of materials for jet-engine components, taking into account temperature requirements.

Metals & Alloys, Nonferrous

Zirconium. I—Production. II—Treatment of the Metal. III—Properties and Uses. G. L. Miller. *Nuclear Eng.*, May, June, July, 1956, pp. 58–62, 111–115, 164–168. 15 refs. Description of production methods; forging, rolling, and extruding processes; and basic physical and mechanical properties, taking into account corrosion resistance and alloying.

Creep of Polycrystalline Aluminum as Determined from Strain Rate Tests. J. Weertman. *J. Mech. & Phys. Solids*, Aug., 1956, pp. 230–234. Test results for high purity aluminum specimens in a strain-rate machine over a wide temperature range. From the experimental results, an empirical relation for strain rate is determined considering maximum stress and temperature.

The Fatigue Strength of Aluminum Alloy Sheet to Spec., D.T.D.546, Using Specimens of Two Different Sizes. N. J. Wadsworth. *Gt. Brit., RAE TN Met. 237*, Apr., 1956. 12 pp. 14 refs.

Typical Tensile Stress-Strain Relationships for Aluminum Alloy Sheet to Specifications D.T.D.546B, D.T.D.646B and D.T.D.687A. F. Clifton. *Gt. Brit., RAE TN Struc. 191*, Apr., 1956. 31 pp.

The Variation of Tensile Strength in Large Aluminum Alloy Extruded Bar to Specifications D.T.D.363A, D.T.D.364B and D.T.D.683. A. G. Cole. *Gt. Brit., RAE TN Struc. 190*, May, 1956. 40 pp.

Aluminum-Legierungen für die Luftfahrt. P. Krekel and K. Reichel. *Luftfahrttechnik*, Mar. 15, 1956, pp. 45–48. 21 refs. In German. Evaluation of aluminum and its alloys in terms of strength, temperature, stress, and corrosion resistance.

Mechanical Tests on Specimens from Large Aluminum-Alloy Forgings. James A. Miller and Alfred L. Albert. *U.S., NACA TN 3729*, Aug., 1956. 25 pp.

Magnesium Design Notes. *Mag. of Magnesium*, Aug., 1956, pp. 2–5. Outline of magnesium properties covering weight reduction, stiffness - to - weight ratio, strength-to-weight ratio, resistance to fatigue, damping capacity, hardness and resistance to wear, tensile strength at elevated temperatures, machinability, resilience, and formability.

Tensile Properties of AZ31A-O Magnesium-Alloy Sheet Under Rapid-Heating and Constant-Temperature Conditions. Ivo M. Kurg. *U.S., NACA TN 3752*, Aug., 1956. 21 pp. Experimental investigation of specimens heated to rupture at nominal rates of 0.2°F. to 100°F. per sec. under constant tensile load conditions, with results compared to those of conventional tensile stress-strain tests at elevated temperatures after 1/2-hour exposure.

Tensile Properties of HK31XA-H24 Magnesium-Alloy Sheet Under Rapid-Heating Conditions and Constant Elevated Temperatures. Thomas W. Gibbs. *U.S., NACA TN 3742*, Aug., 1956. 20 pp.

Titanium—Its Properties and Possible Applications. O. Rüdiger, H. van Kann, and W. Knorr. (*Tech. Mitteil. Krupp*, No. 2, 1955, pp. 23–38.) *Gt. Brit., MOS TIL/T4558(A)*, May, 1956. 28 pp. 31 refs. Translation.

The Corrosion Chemistry of Titanium. K. Jordan and R. W. Fischer. (*Tech. Mitteil. Krupp*, No. 2, 1955, pp. 44–47.) *Gt. Brit., MOS TIL/T4558(C)*, May, 1956. 9 pp. Translation. Description of tests in which titanium and stainless steel were exposed to several corrosive media for a period of 50 to 100 days.

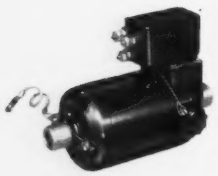
Titan in der Werkstatt. R. W. Schulz. *Luftfahrttechnik*, July 15, 1955, pp. 54–56. In German. Analysis of basic titanium characteristics, with emphasis on welding, machining, and finishing.

Nonmetallic Materials

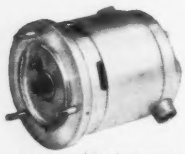
Time Dependence of Mechanical Breakdown Phenomena. Bernard D. Coleman. *J. Appl. Phys.*, Aug., 1956, pp. 862–866. 11 refs. Presentation of a phenomenological theory applicable to creep failure

Explosion-proof vacuum unit.

Thoroughbred Fractional HORSEPOWER for your motor-driven products



Aircraft windshield wiper motor.



A rugged high-torque, high-speed motor.

The unexcelled performance of Lamb Electric Motors in many types of industrial, commercial and domestic products is evidence of their outstanding quality.

Dependability and efficiency (optimum weight-size-horsepower ratio) are features that result from proper design and careful manufacture by personnel having many years of experience in the small motor field.

May we demonstrate how Lamb Electric Motors can bring these advantages — and also perhaps lower costs — to your products?

THE LAMB ELECTRIC COMPANY • KENT, OHIO

In Canada: Lamb Electric — Division of Sangamo Company Ltd. — Leaside, Ontario

Lamb Electric

SPECIAL APPLICATION FRACTIONAL HORSEPOWER MOTORS

FOR YOUR
1957 Advertising Program

AERONAUTICAL ENGINEERING REVIEW

For your monthly advertising messages to the aircraft industry's engineering and design personnel—the men who influence buying.

NEW MEDIA BROCHURE Now Available!

6 pages of FACTS on the Aeronautical Engineering Review.

Write for your free copy TODAY!

OFFICIAL PUBLICATION:
INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

2 East 64th Street
New York, New York

of oriented polymeric filaments under tensile stresses. Experiments involving drawn 66 nylon monofilament yarn are cited to show how the parameters which describe the average lifetime under dead-load behavior of a yarn may be used to calculate its tensile strength distribution when measured with a constant-rate-of-loading apparatus.

Testing

Utilisation des Compteurs de Geiger-Müller à l'Étude de Variations de Texture de Laminage Suivant la Température de Déformation. Francis Provost. *France, Min. de l'Air PST 313*, 1956. 56 pp. 24 refs. SDIT, 2 Av. Porte-d'Issy, Paris 15, Frs. 800. In French. Analysis of the application of Geiger counters to quantitative radio-crystallography studies under the assumption that the X-ray generator is powerful enough and that the measuring system used permits the desired precision (rapid-measurement integrator, precise-measurement numerator) to be reached. An example of application is cited when the quantitative method is used in conjunction with microscopy.

O Pełzaniu i Pełzarce. Jan Madejski. *Rozprawy Inżynierskie* (Warsaw), No. 1, 1956, pp. 43–69. In Polish. Investigation of two types of material, one a piece with more or less constant cross-section and the other a ductile material with a considerable reduction in cross-sectional area before fracture. From these tests a theory is proposed for long-time tensile tests of materials on a vertical machine.

Mathematics

Fundamentals of Analysis of Variance. I—The Analysis of Variance (ANOVA) Model. Charles R. Hicks. *Ind. Quality Control*, Aug., 1956, pp. 17–20. Description of a technique using as an illustrative example the calculation of the effect of nozzle type on the rate of fluid flow measured in cubic centimeters.

On the Iterated Wave Equation. Dorothee Krahn. *U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-73 (AFOSR TN 56-239)*, May, 1956. 31 pp. Establishment of a theorem on the decompositions of the general solution of the iterated wave equation in terms of solutions of the Euler-Poisson-Darboux equation, and derivation through the use of a particular decomposition of a solution to the Cauchy problem for the equation $L_0^n(w) = 0$ with initial conditions on the boundary $t = 0$.

On Subharmonic Functions and Differential Geometry in the Large. Alfred Huber. *U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-72 (AFOSR TN 56–261)*, May, 1956. 92 pp. 33 refs. Treatment of problems pertaining to differential geometry in the large by function theoretical methods.

Non Degenerate Surfaces of Finite Topological Type; Analytical Theory of Continuous Transformations. W. H. Fleming. *Purdue U., Dept. Math., TN 5 (AFOSR TN 56–351)*, July, 1956. 7 pp. Generalization of Morrey's theorem to include surfaces of the topological type of any compact connected 2-manifold, whether orientable or not, and with or without boundary.

RADIO TELEMETRY
Second Edition

By MYRON H. NICHOLS, Ramo-Wooldridge Corporation and LAWRENCE L. RAUCH, University of Michigan

Here, for the first time in a unified and comprehensive form, is all the material on radio telemetry that has previously been available only in scattered and uncorrelated papers. Its complete coverage of theory, methods and techniques includes these noteworthy features:

- **Identification and theoretical analysis of important design parameters.**
- **Noise analysis of various methods of modulation and multiplexing.**
- **Illustrations of circuits and instruments used in data transmissions.**
- **Practical, theoretical considerations for the design and development of new equipment.**

1956 461 pages 206 illus. $12.00

ROCKET PROPULSION ELEMENTS
An Introduction to the Engineering of Rockets
Second Edition

By GEORGE P. SUTTON, Univ. of California

This popular book, now revised and 45% larger, presents a broader treatment of the basic elements and a fuller description of the physical mechanisms, applications, and designs of rocket propulsion systems. The *only* technical book on this specific subject, its material is organized into three categories:

1. **Liquid propellant rockets, their working fluids, and their design.**
2. **Solid propellant rocket fundamentals, working substances, and solid propellant rocket design.**
3. **General principles of thermodynamics, chemistry, heat transfer, flight theory, historical background, and testing methods.**

1956 483 pages 190 illus. $10.25

Mail this coupon today for your ON-APPROVAL copies!

JOHN WILEY & SONS, INC. AER-106
440 Fourth Avenue, New York 16, N. Y.
Please send me the book(s) checked to read and examine ON APPROVAL. Within 10 days I will return the book(s) and owe nothing, or I will remit the full purchase price, plus postage.

☐ RADIO TELEMETRY, $12.00
☐ ROCKET PROPULSION ELEMENTS, $10.25

Name.....
Address.....
City..... State.....

☐ SAVE POSTAGE! Check here if you ENCLOSE payment, in which case we pay postage. Same return privilege, of course.

TECHNOLOGICAL

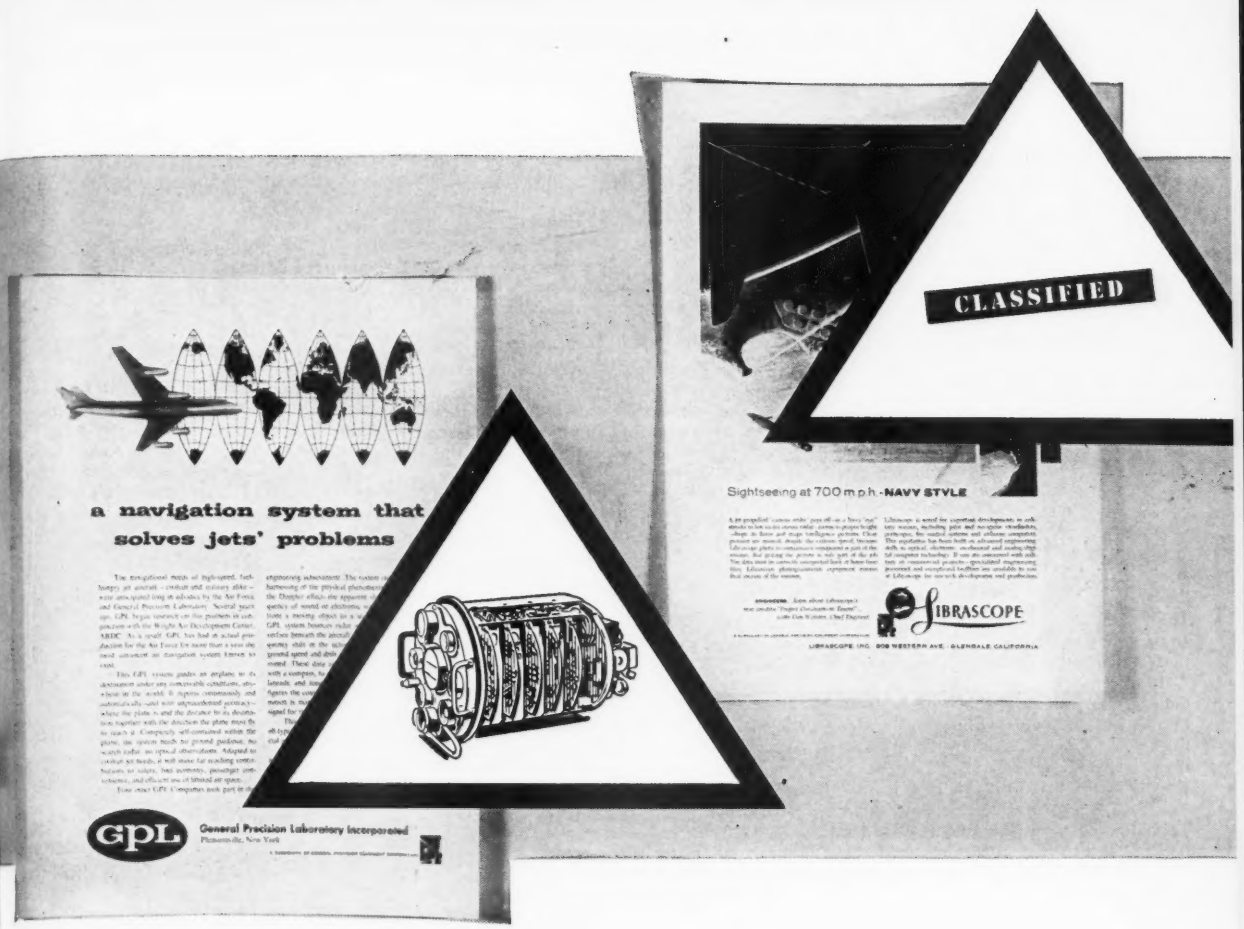
AERONAUTICAL SYSTEMS have made vital contributions to the progress of jet aviation and its expansion into the civil transport field. Many have won recognition as the finest in the industry, bench marks of American technology.

Whole generations of airmen, for instance, have been trained in flight simulators developed and produced by Link, pioneer of on-the-ground flight training. This GPE Company has delivered over 800 jet flight simulators—more than all other manufacturers put together. It has just been selected, on the basis of superior technology and equipment, to produce America's first simulators for jet air liners. Link-developed DC Computer Systems in Link supersonic simulators are the only ones meeting the needs of these advanced aircraft.

Equally dominant are the gyro-magnetic compass systems of Kearfott, another GPE Company. This company's new lightweight J-4 Compass System weighs only

GENERAL PRECISION E

92 GOLD STREET, NEW YORK 38, NEW YORK



BENCH MARKS

18 pounds. Yet it provides accurate heading information at all latitudes, is rugged enough to maintain its high accuracy despite the jolts and speeds of jet flight. The Air Force has just selected it as standard for all new fighter craft. Kearfott's N-1 Compass System has been the navigational standard for Air Force bombers for 5 years.

Still another member of the GPE Group, General Precision Laboratory, has developed and is currently making quantity deliveries of the most advanced airborne navigation systems in use. These GPL systems, which are self-contained and fully automatic, have flown millions of operational miles with unprecedented accuracy. Their adaptations to civilian jet needs—GPL's RADAN Systems—are expected to make equally far reaching contributions to the commercial jet transport field—in the way of increased safety, fuel economy, passenger convenience and efficient use of limited air space.

These are but some of the accomplishments in aviation for which GPE Companies, working in conjunction with the Armed Services, are responsible. Librascope, an important member of the Group, produces outstanding instruments and equipment for the field. Librascope's computers, its highly advanced equipment for photo-reconnaissance work and photogrammetric equipment for the interpretation of photo data, its periscopes, pilot and navigator finders, are all leaders. Several GPE Companies are deeply involved in inertial guidance, guided missile projects and certain nuclear power applications.

In all GPE achievements in the numerous industries in which the companies work, GPE Coordinated Precision Technology plays an important part by inter-relating the wide range of skills and resources of the Group. This operating policy, and each company's unremitting insistence on highest quality, are major reasons for the frequency with which GPE systems and equipment continue to set standards in their fields.

N EQUIPMENT CORPORATION

THE GPE GROUP

Ampro Corporation • *Askania Regulator Company* • *Bizzelle Cinema Supply Corporation* • *Bludworth Marine*
General Precision Laboratory Incorporated • *The Griscom-Russell Company* • *The Hertner Electric Company* • *International Projector Corporation*
Kearfott Company, Inc. • *Librascope, Incorporated* • *Link Aviation, Inc.* • *J. E. McAuley Mfg. Co.* • *National Theatre Supply*
Pleasantville Instrument Corporation • *Precision Technology, Inc.* • *SEC-o-matic Corporation* • *Shand and Jurs Co.*
Society for Visual Education, Inc. • *The Strong Electric Corporation* • *Theatre Equipment Contracts Corporation*

An Algorithm for Quadratic Programming. Marguerite Frank and Philip Wolfe. *Nav. Res. Logistics Quart.*, Mar., June, 1956, pp. 95–110. 14 refs. Description of a finite iteration method for calculating the solution of quadratic programing problems, with suggested extensions to more general nonlinear problems.

B-Sets and Fine Cyclic Elements; Analytical Theory of Continuous Transformations. Christoph J. Neugebauer. *Purdue U., Dept. Math., TN 4 (AFOSR TN 56–356)*, July, 1956. 38 pp. ARDC-supported study.

On Surfaces of the Type ν; Analytical Theory of Continuous Transformations. Lamberto Cesari. *Purdue U., Dept. Math., TN 3 (AFOSR TN 56–358)*, Apr., 1956. 76 pp. 13 refs. Discussion of the concept of retraction for continuous mappings $S = (T, A)$ from a finitely connected Jordan region $A = J$, or mappings, or surfaces of the ν-type, where ν is the connectivity of J, $0 \leqslant \nu < +\infty$.

Some Rationality Questions on Algebraic Groups. Maxwell A. Rosenlicht. *Northwestern U. AFOSR TN 56–318*, July, 1956. 43 pp. 10 refs. Extension, to include the case where k is an arbitrary perfect field, of Chevalley's proof that, if G is a connected linear algebraic group defined over a field k, then the field $k(G)$ of rational functions on G that are defined over k is k-isomorphic to a subfield of a purely transcendental extension of k when k is any field of characteristic zero.

A Two-Phase Method for the Simplex Tableau. Harvey M. Wagner. *Operations Res.*, Aug., 1956, pp. 443–447. Method for manually solving linear-programing problems in which artificial vectors are introduced and subsequently driven out.

Osculatory Extrapolation and a New Method for the Numerical Integration of Differential Equations. Herbert E. Salzer. *J. Franklin Inst.*, Aug., 1956, pp. 111–120.

On the Evaluation of the Schwarz Function. Yudell L. Luke and Henry E. Fettis. *J. Aero. Sci.*, Oct., 1956, pp. 975, 976. Solution by representation of the Bessel function (J_0) as a circular function. Application is made to a problem in supersonic panel flutter.

A Least Squares Matrix Interpolation of Flexibility Influence Coefficients. Alfred F. Schmitt. *J. Aero. Sci.*, Oct., 1956, p. 980. Method of matrix interpolation based upon a weighted least-squares curve-fitting procedure, in order to permit interpolation from a structural net of points to a larger aerodynamic net.

Notes on the Theory of Dynamic Programming; IV—Maximization over Discrete Sets. Richard Bellman. *Nav. Res. Logistics Quart.*, Mar., June, 1956, pp. 67–70. Application of the theory of dynamic programing to a class of problems involving maximization over discrete sets. The solution is derived in order to depend on the solution of a class of functional equations.

Meteorology

A New Method for the Determination of the Vertical Distribution of Ozone from a Ground Station. Edward S. Epstein, Charles Osterberg, and Arthur Adel. *J. Meteorology*, Aug., 1956, pp. 319–333. 20 refs. USAF-sponsored development of a procedure which makes use of infrared and ultraviolet observations to complement one another. Includes detailed discussion of the theoretical background, description of the techniques of its application, and results of such application to data collected over a period of 7 months.

Adiabatiche Reversibili per Aria Satura. Giorgio Fea. *Riv. Meteorologia Aero.*, Apr.-June, 1956, pp. 15–20. In Italian. Description of a graphical method for obtaining solution of the reversible adiabatics equation for saturated air, a method that can be used both as a proper didactic means and in view of the actual calculation for tracing adiabatics on thermodynamic diagrams.

Special Issue: A Discussion on Radiative Balance in the Atmosphere. *Proc. Royal Soc. (London), Ser. A*, Aug. 2, 1956, pp. 145–226. 178 refs. Contents: Introductory Remarks, H. S. W. Massey. The Pattern of Radiative Heating and Cooling in the Troposphere and Lower Stratosphere, F. Möller. The Computation of Radiative Heating Rates in the Atmosphere, A. R. Curtis. High-Resolution Spectroscopy of Minor Atmospheric Constituents, M. Migeotte. The Use of Surface Observations to Estimate the Local Energy Balance of the Atmosphere, G. D. Robinson. Solar Infra-Red Spectroscopy from High-Altitude Aircraft, F. E. Jones and V. Roberts. Some Measurements of the Flux of Infra-Red Radiation in the Atmosphere, A. W. Brewer and J. T. Houghton. Origin and Distribution of the Polyatomic Molecules in the Atmosphere, G. M. B. Dobson. Thermal Radiation in the Upper Atmosphere, A. R. Curtis and R. M. Goody. The Thermosphere, D. R. Bates. Study of Solar Radiation at High Altitudes Using Rocket-Borne Instruments, R. L. F. Boyd. Absorption of Ultra-Violet Radiation by the Atmospheric Gases, R. W. Ditchburn.

Military Aviation & Armament

Aims of the Air Force Development Program in Aeronautics and Propulsion. Marvin C. Demler. *Aero. Eng. Rev.*, Oct., 1956, pp. 59–61, 70. Description of the USAF planning process in technological development and outline of general goals.

The Relevance of Costs in Operations Research. Malcolm W. Hoag. *Operations Res.*, Aug., 1956, pp. 448–459. Application of theoretical precepts to the question of why and when cost measures are needed in operations research.

Missiles

Cohetes, Cohetería. Teófilo M. Tabanera. *Rev. Asoc. argent. Interplan., Apr.-June, 1956*, pp. 17–25. In Spanish. Discussion of missile development with data on various designs.

Improved On-Off Missile Stabilization. Robert W. Bass. *Jet Propulsion*, Aug., 1956, pp. 644–648, 643. 16 refs. Derivation of a procedure for on-off control systems by which the delays (due to time lag and hysteresis in the system) can be completely eliminated.

Optimum Rocket Trajectories. Burton D. Fried and John M. Richardson. *J. Appl. Phys.*, Aug., 1956, pp. 955–961. General considerations leading to the derivation of equations for the optimum altitude angle for both constant and Kepler force fields, the results of which provide a convenient means of estimating an upper limit for the achievable range of a given missile.

Nuclear Energy

The Use of Nuclear Radiation in Combustion Research. Martin E. Gluckstein, Richard B. Morrison, and John V. Nehemias. *Jet Propulsion*, Aug., 1956, pp. 637–643. Analysis of the interaction of nuclear radiation with fuel-oxidant system causing increased rates of chemical reaction.

Photography

Effect of Camera Tipping on the Location of the Principal Point. Francis E. Washer. *J. Res.*, July, 1956, pp. 31–39. 13 refs. USAF-sponsored development of a method whereby the magnitude and direction of the angle of camera tipping can be determined from an analysis of the asymmetric values of distortion for the case of the object lying at equal but opposite angles from the central line of sight, in order to calculate the displacement of the central image from the principal point of autocollimation. Results are confirmed by experiment.

Physics

Emission Band Spectra of Nitrogen; The Lyman-Birge-Hopfield System. Alf Lofthus. *Can. J. Phys.*, Aug., 1956, pp. 780–789. 10 refs. ARDC-sponsored photographic investigation and analysis of thirteen a-X bands in the near ultraviolet region under high resolution to obtain refined rotational and vibrational constants for the a and X states.

Gravitationsforschung in den USA. Henri Long. *Flugwelt*, Aug., 1956, pp. 504–506. In German. Survey of research in gravitation in the United States, related to problems encountered in airplane, rocket, and gyroscopic device construction.

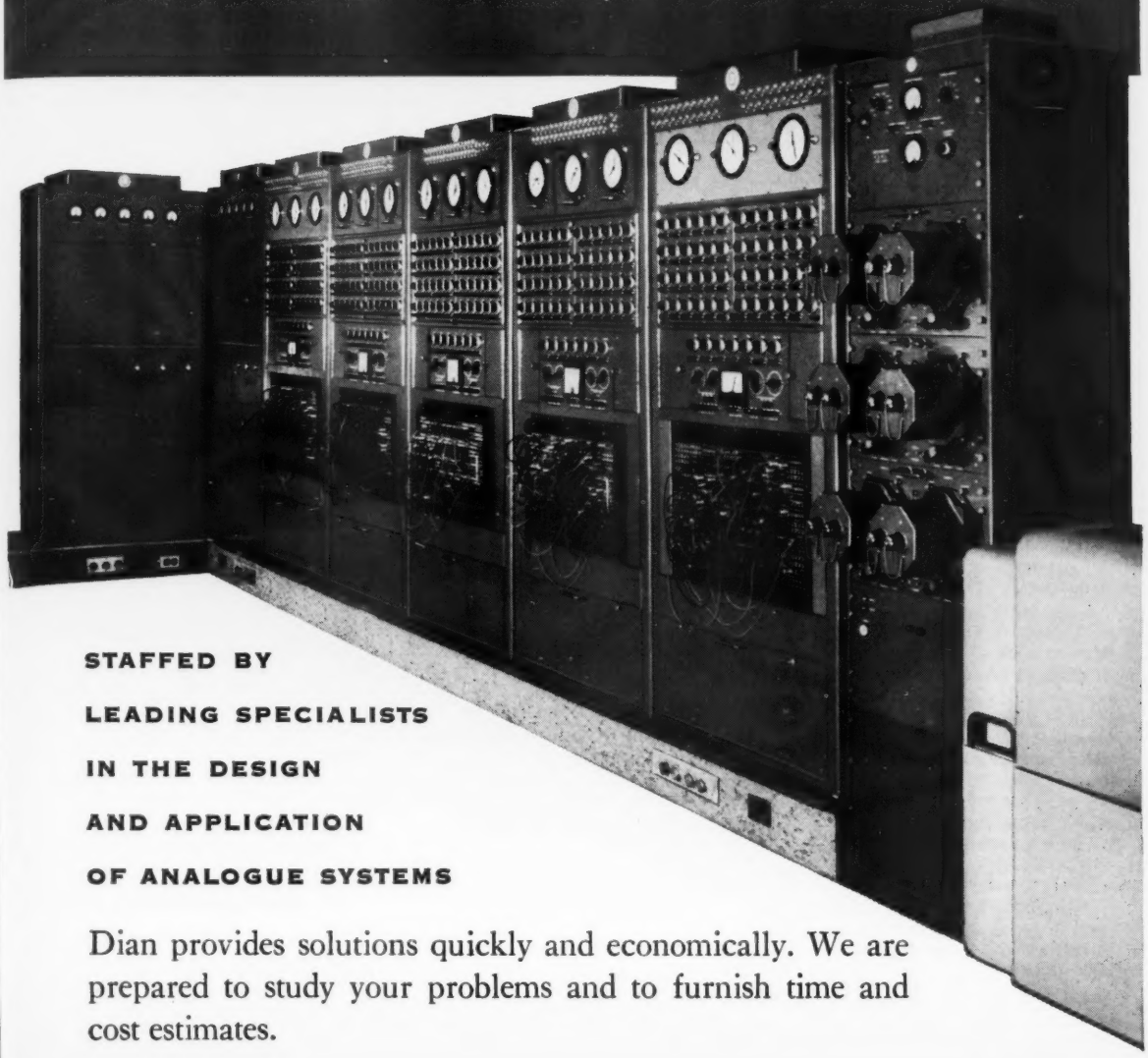
The Strengths, Widths, and Shapes of Infrared Lines. I—General Considerations. II—The HCl Fundamental. William S. Benedict, Robert Herman, Gordon E. Moore, and Shirleigh Silverman. *Can. J. Phys.*, Aug., 1956, pp. 830–875. 48 refs. USAF-ONR-supported analysis of methods for deriving the strengths, widths and shapes of spectral lines from measurements obtained with spectrometers having resolving power sufficient for separating individual spectral lines but insufficient for portraying the true contour line accurately. Detailed application of these methods to the vibration-rotation lines of the 1–0 bands of HCl^{35} and HCl^{37} observed at 300°K. is outlined.

NOW AVAILABLE

TO GOVERNMENT AND INDUSTRY —

A HIGH ACCURACY • HIGH PRECISION

ANALOGUE COMPUTING SERVICE



STAFFED BY
LEADING SPECIALISTS
IN THE DESIGN
AND APPLICATION
OF ANALOGUE SYSTEMS

Dian provides solutions quickly and economically. We are prepared to study your problems and to furnish time and cost estimates.

DIAN LABORATORIES, INC.

611 BROADWAY • NEW YORK 12, NEW YORK • ALGONQUIN 5-8811

IN CANADA: DATA PROCESSING ASSOCIATES, LTD.

1313 WELLINGTON STREET • OTTAWA, CANADA

Fairchild Engine Division and Gas Turbine Laboratory present IMPORTANT ENGINEERING OPPORTUNITIES

Fairchild Engine Division is now expanding its engineering staffs in its plant and Gas Turbine Laboratory at Deer Park, Long Island, New York.

Investigate these opportunities:

MECHANICAL DESIGN ENGINEERS

For mechanical design of turbojet engines and components, and to conduct preliminary design study investigations on gas turbine engines.

MECHANICAL DESIGN ANALYTICAL ENGINEERS

To work closely with design engineers and to make recommendations as a result of analytical studies, with respect to stress analysis of lightweight rotating machinery, vibration, analysis, cycle analysis investigations, analysis of mechanical component functionings and general structural problems.

RESEARCH ENGINEERS

Advanced degree, preferably in the fields of applied physics, chemistry, aerodynamics or applied mechanics. Also: engineers with supersonic aerodynamics background with high speed aircraft or wind tunnel testing.

AIRCRAFT SYSTEMS ANALYSIS

Mission analysis for aircraft systems. Familiar with engine-airframe mission analysis for modern aircraft.

DEVELOPMENT ENGINEERS

Aeronautical and Mechanical Engineers to plan, supervise and conduct development test programs with gas turbine engines and components.

EQUIPMENT ENGINEERS

Familiar with mechanical test equipment design, including high speed rotating machinery and equipment.

ENGINE VIBRATIONS ENGINEERS

To determine means of measuring stress and shock loads in test articles. Area of operations is concerned with turbine engine vibration characteristics associated with high speed rotating parts subject to high temperatures and high stress loads.

And, Engineers with experience in other allied mechanical or aeronautical fields such as:

Instrumentation Engineers; Compressor Aerodynamic Designers; Performance Analytical Engineers; Engine Controls Engineers; Test Engineers; Equipment and Product Drafting Checkers, and Mechanical Design Layout Men.

Please Contact Felix Gardner

FAIRCHILD

ENGINE DIVISION • DEER PARK, L. I., N.Y.

A Division of Fairchild Engine and Airplane Corporation

...WHERE THE FUTURE IS MEASURED IN LIGHT-YEARS!

O Primenenii Vtorogo Metoda A. M. Liapunova dlia Uravnenii s Zapazdyvaniiami Vremeni. N. N. Krasovskii. *Prikl. Mat. i Mekh.*, May-June, 1956, pp. 315–327. 12 refs. In Russian. Development of a procedure for the generalization of the Liapunov functional method with retardation of time, based on an analysis of stability equations.

Turbulent Dispersion of Dynamic Particles. Vi-Cheng Liu. *J. Meteorology*, Aug., 1956, pp. 399–405. 16 refs. USAF-sponsored determination of the statistical particle-dispersion parameters in terms of the spectrum density of the turbulent field and of the physical characteristics of the particles by means of Wiener's generalized harmonic-analysis method. Discussion is restricted to one-dimensional problems; the turbulent field is assumed to be stationary, homogeneous and isotropic; and results are valid only when the particles are so sparsely distributed that the dynamic effect of the embedded particles on the fluid can be ignored.

Diffraction by a Wide Slit. S. N. Karp and A. Russek. *J. Appl. Phys.*, Aug., 1956, pp. 886–894. 11 refs. USAF-sponsored theoretical investigation of the problem of diffraction of scalar waves by an infinite conducting plane with a slit.

Recording Decay of Electron Density in Ionized Gases. G. E. Deakins and C. M. Crain. *Rev. Sci. Instr.*, Aug., 1956, pp. 606–608. WADC-sponsored research describing a method for the measurement and photographic recording of electron density loss in an ionized gas using a microwave system operating near 9,400 mc.

Power Plants

Sul Redimento Termico del Motore Composto di un Compressore a Pistoni Liberi e d'Una Turbine a Gas. Giuseppe Ferraro Bologna. (*Atti Acad. Sci. Torino*, Vol. 90, 1955–1956.) *Torino Polytech. Inst., Aero. Lab., Monograph 372*, Nov. 23, 1955. 8 pp. In Italian. Analysis of the thermal efficiency of a free-piston-compressor/gas-turbine compound engine.

Jet & Turbine

Turbojet Cycle Analysis: The Effects of Liquid Injection at Several Points in the Cycle. Appendix A—Derivation of Equations. E. P. Cockshutt. *Canada, NAE LR 164*, Apr., 1956. 28 pp. Calculation of the effects for liquid injection both upstream and downstream of the turbine. The responses of the peak cycle temperature, engine fuel flow, tailpipe pressure, gross thrust and turbine pressure ratio are given for a range of liquid latent heats and gas Mach Numbers. The equations derived include working equations for preturbine and tailpipe injection, and relations between engine fuel flow and peak cycle temperature and between engine thrust and tailpipe pressure.

Calculul Variației Caracteristicilor Turboreactorului în Funcție de Condițiile de Funcționare. Paul Constantinescu. *Rev. Transp.*, No. 6, 1956, pp. 237–244. In Rumanian. Development of a method for calculating turboengine thrust and fuel consumption as they depend on altitude,

flight speed, and other operating conditions.

Turbines de Servitudes por l'Entrainement d'Accessoires. Y. Conan. *Tech. et Sci. Aéronautiques*, No. 3, 1956, pp. 140–146. In French. Analysis of a pneumatic auxiliary system in which compressed air is obtained from the main power-plant compressor.

Entwicklungstendenzen bei Brennkammern für Strahltriebwerke. O. Lutz and W. Alvermann. *Luftfahrttechnik*, Aug. 15, 1955, pp. 58–62. In German. Survey of developments in the design of jet-engine combustion chambers.

Probleme der Selbstzündung und Verbrennung bei der Entwicklung der Hochleistungskraftmaschinen. Fritz A. F. Schmidt. *Nordrhein-Westfalen, Arbeitsgemeinschaft für Forschung, Heft 50*, 1956, pp. 7–27; Discussion, pp. 29–34. In German. Summarized evaluation of available data related to autoignition and combustion in the development of high-performance power plants. Experimentally obtained data are analyzed for a classification according to specific characteristics, and the applicability of experimental methods is determined.

A Method of Correction of Compressor Characteristics for Change of Working Fluid Specific Heat. S. J. Moyes. *Gt. Brit., NGTE Memo. M. 276*, July, 1956. 13 pp. Development of a method based on aerodynamic relationships for determining the effect of changes in specific heat on axial-flow compressor characteristics.

Big Engines or Small. *The Aeroplane*, Aug. 10, 1956, pp. 189–191. Discussion of weight versus performance in design of jet engines for fighter aircraft.

Four Derby Winners—Rolls-Royce Commercial Gas Turbines. *Flight*, Aug. 17, 1956, pp. 249–253. Discussion of the development and performance characteristics of the Rolls-Royce Dart, Tyne, Avon, and Conway engines.

Gasturbinen mit Zentripedalrädern. W. Gundermann. *Luftfahrttechnik*, Nov. 15, 1955, pp. 125–127. 13 refs. In German. Developmental survey of centripetal installations in gas-turbine engines.

Fuel System Icing. E. R. Schuberth. *Lockheed Field Serv. Dig.*, Sept.-Oct., 1956, pp. 1–10. Description of research into the characteristics and causes of icing and discussion of preventive methods currently in use and future methods under investigation.

Le Réallumage des Turboréacteurs en Altitude. F. Ferrié. *Tech. et Sci. Aéronautiques*, No. 3, 1956, pp. 113–117. In French. Study of the problem of reignition of turbojets at high altitudes, taking into account pressure, temperature, and velocity factors, with a discussion of different reignition systems used.

Turbine Disks for Jet Propulsion Units—An Account of Work of the Disk Panel of the Ministry of Supply, Gas Turbine Collaboration Committee, During the Years 1941–1949. II. A. E. Johnson. *Aircraft Eng.*, Aug., 1956, pp. 265–272. Discussion covering the determination of plastic strain caused by yielding, its effect on stress, and the effect of creep.

The Fouling of Turbine Blades by Fuel Ash. V—Corrosion Tests with Various Heat Resisting Materials. F. S. E. Whitcher. *Gt. Brit., NGTE Rep. R.192*, June, 1956. 36 pp. 11 refs. Experimental investigation involving a series of rig tests to determine the resistance of selected materials to accelerated oxidation by vanadium bearing fuel oil ash, with results indicating that alloys based on nickel or cobalt are more resistant to this type of corrosion than those based on iron.

Ram-Jet & Pulse-Jet

Ramjet Engine. *The Engr.*, Aug. 10, 1956, p. 203. Description of Bristol Aero-Engine aerothermodynamic duct for missile propulsion.

Bristol and Napier Ramjets. *The Aeroplane*, Aug. 10, 1956, pp. 178, 179. Description of two British ram-jets giving design characteristics.

Staustrahlantrieb. Eugen Sänger. *Luftfahrttechnik*, July 15, 1956, pp. 131–140. In German. Evaluation of ram-jet aircraft in military and civil application, operating range, limitations, production and maintenance cost, and some problems encountered in the design of power plants.

La Représentation Graphique des Phénomènes se Présentant dans les Chambres de Combustion et Statoréacteurs. Otto Lutz. *Tech. et Sci. Aéronautiques*, No. 3, 1956, pp. 105–112. In French. Graphical presentation of phenomena encountered in combustion chambers and in ram-jets.

Reciprocating

Verifiche Sperimentali di una Analogia Idrodinamica Valida per Canali d'Aspirazione di Motori Alternativi. Carlo Arneodo. (*Riv. ATA Richerche*, Jan., 1956.) *Torino Polytech. Inst., Aero. Lab., Monograph 379*, Jan., 1956. 5 pp. Experimental verification of a hydrodynamic analogy valid for reciprocating engine intakes.

Rocket

Combustion Processes in Liquid Propellant Rocket Motors (Third Quarterly Progress Report for the Period 1 March 1956 to 31 May 1956). I. E. Smith and I. Glassman. *Princeton U. Dept. Aero. Eng. Rep. 334-c*, June 29, 1956. 12 pp. Experimental investigation, using a specially designed apparatus, to determine the effect of temperature, pressure, and relative particle velocity on the ignition delay time and rate of energy release. Includes a description of the apparatus.

Some Tests of Injectors for Rocket Motors Using Liquid Oxygen. J. Humphries and W. H. J. Riedel. *Gt. Brit., RAE TN R.P.D.140*, Feb., 1956. 25 pp. Comparison of various injection systems on a 900-lb. thrust scale, in terms of economy of propellant consumption and of component manufacturing ease, as a step in the design of a 4,000-lb. thrust liquid-oxygen/kerosene aircraft rocket motor with variable thrust.

Design and Performance of a Thrust Transducer. Loren E. Bollinger. *ISA J.*, Aug., 1956, pp. 260–264. WADC-sponsored discussion of the requirements of an instrument for measuring the mechanical output of small-scale rocket engines, with performance data and description of the operating characteristics of a bonded strain-gage type of transducer used in rocket-engine tests over a 16-month period.

Production

Metalworking

Deep-Hole Boring. H. J. Pearson. *Aircraft Prod.*, Sept., 1956, pp. 344–350. Discussion of the deep-hole boring process, including description of machining equipment, boring operations, and tool-head design.

Synthetic-Resin Bonding; The Use of Redux and Araldite Adhesives in the Australian Jindivik Aircraft. I—Constructions; Bonding Technique; Tooling Methods. II—Component Assembly: Structural Tests. G. D. Bennett. *Aircraft Prod.*, Aug., Sept., 1956, pp. 300–305, 383–390.

Large Forgings; Some Observations on Their Manufacture in High-Strength Aluminium-Alloys. C. Wilson. *Aircraft Prod.*, Sept., 1956, pp. 374–382.

Hot Forming—Application of the Redwing-Nunn Process to Parabolic-Section Stretch-Forming. *Aircraft Prod.*, Sept., 1956, pp. 391, 392.

Streckformen—Eine neue Art der Blechformung im Flugzeugbau. Frank B. Lane. *Luftfahrttechnik*, Sept. 10, 1955, pp. 91–96. In German. Description of metal-forming techniques.

Experiments in Plane-Strain Extrusion. W. Johnson. *J. Mech. & Phys. Solids*, Aug., 1956, pp. 269–282. 13 refs. Results of plane-strain extrusion of lead and aluminum with dies of semiangle of 30, 45, 60, 75, and 90 degrees. Includes comparison of experimental values with those predicted by the use of slip-line field methods.

Flange Wrinkling in Deep-Drawing Operations. B. W. Senior. *J. Mech. & Phys. Solids*, Aug., 1956, pp. 235–246. Determination of the critical dimensions of a deep-drawn flange and the number of waves into which it will collapse on wrinkling. Predictions are based on the stress-strain curve of the material and on the flange geometry.

The Heating of Ferromagnetic Bodies by High Frequency Induction. M. G. Ribaud. (*Bul. Un. Exploit. Elec. Belgique*, No. 3, 1955, pp. 26–36.) *Gt. Brit., RAE Lib. Transl. 582*, June, 1956. 12 pp. 13 refs. Discussion, based on experimental results, of the phenomena occurring in both strong and weak fields, the influences of hysteresis and temperature, and the propagation of heat into the interior of the body. Includes description of a method for calculating the power dissipated by the Foucault currents.

Machining Light-Alloys. *Aircraft Prod.*, Aug., 1956, pp. 318–324. Discussion of the applications and advantages of special cutting tools for progressive-cut milling, trepan boring, internal-radius profiling, and magnesium-tube profiling. A description of milling-cutter design is given, and the difficulties encountered in the early stages of machining are outlined.

Milling High-Tensile Steel. L. G. Burnard. *Aircraft Prod.*, Sept., 1956, pp. 351–353. Application of thread-form serrated cutting edges to cutter teeth

ONLY

AMPHENOL "AN" CONNECTORS

have gold-plated contacts and blue dielectrics!

Although optional under Specification MIL-C-5015B, gold-plated contacts and blue diallyl phthalate dielectrics are *standard* in AMPHENOL AN connectors. Gold-over-silver plating of contacts is used by AMPHENOL because contacts will not tarnish, insuring easy soldering, and because this finish assures lower electrical losses. Diallyl phthalate dielectric material provides extremely high insulation resistance as well as low millivolt drop; it has great strength, low moisture absorption.

Gold-plated contacts, blue dielectrics are offered as standard *only* in AMPHENOL ANs. Only by specifying AMPHENOL AN connectors do you automatically obtain these *plus* features.

AMPHENOL

AMPHENOL ELECTRONICS CORPORATION
chicago 50, illinois
AMPHENOL CANADA LIMITED • *toronto 9, ontario*

giving longer cutter life and faster machining rates.

Superfine Finishing with a Cutting Tool. J. Desherault. (*Rev. Alumin.*, vol. 32, 1955, pp. 701–712.) *Gt. Brit., RAE Lib. Transl. 572*, May, 1956. 18 pp. Method using direct machining with a cutting tool to obtain a surface state of very high standard, three times better than superfine techniques and six times better than diamond finishing or grinding. Results have been checked by recordings with a Brush surface analyzer.

How to Select and Apply Small Rivets for High Production Jobs. T. C. Buchanan. *Mach. Des.*, Aug. 23, 1956, pp. 97–103. Discussion of types, materials, assembly procedure, and design tips for rivet assemblies.

New Final Assembly Methods Used to Build FD-1 Delta Type Fighter. C. H. Smartt. *Auto. Ind.*, Aug. 15, 1956, pp. 48–52.

Tooling

Neuzeitliche Werkzeugmaschinen für den Flugzeugbau. R. W. Schulz. *Luftfahrttechnik*, Sept. 10, 1955, pp. 85–88. In German. Discussion of machine tools for air-frame production.

Sequence-Control; Development by Ian Nickols Ltd., of an Electropneumatic Control-System for the Automatic Operation of Machine-Tools. *Aircraft Prod.*, Sept., 1956, pp. 364–373.

Propellers

Propellers for Military and Civil Aircraft. L. G. Fairhurst. *J. RAeS*, Aug., 1956, pp. 515–522. Discussion of design and production factors, propeller hubs, and accessories. Includes safety feature requirements; aerodynamics of the blade section, considering aircraft performance; and such problems as reversing propeller thrust, shaft brake, deicing, vibration, and noise.

Refueling in Flight

Sistema de Sonda y Boya en el Aprovisionamiento Aereo de Combustible. Charles A. Speas. *Rev. Aérea Latinoamericana*, Mar., 1956, pp. 6–14. In Spanish. Analysis of refueling-in-flight techniques and of problems encountered.

Rotating Wing Aircraft

First Successful Ground and Airborne Helicopter Blade Tracker Announced by Chicago Aerial Industries. *Am. Helicopter*, July, 1956, pp. 7, 8. Description of new electro-optical device which accurately determines, either on the ground or in the air, the tracking position of any blade in its flight path in the same plane of rotation, in order to minimize vibration caused by out-of-track blades.

"Djinn"—ein Hubschrauber mit bemerkenswerten Flugeigenschaften. *Luftfahrttechnik*, July 15, 1955, pp. 48–53. In German. Design and description of the Djinn helicopter, with details of its aerodynamic performance.

A Report on the Convertawings Quadrotor Helicopter. David H. Kaplan. *AHS Newsletter*, Aug., 1956, pp. 1–6

Discussion covering the aircraft's flight test, reviewing the history of the multiple rotor concept and describing the quadrotor configuration, its weight efficiency, handling qualities, means of control, drive system, and advantages, in terms of vulnerability, vibration reduction, and compactness.

Aerodynamic Aspects of Helicopter Design. Appendix I—**Disturbance Functions for Determining Blade Flapping.** Appendix II—**The Dynamic Longitudinal Stability Criterion.** Appendix III—**The Response to a Step Disturbance Lasting a Finite Time.** H. Roberts. *J. Helicopter Assn. Gt. Brit.*, July, 1956, pp. 24–60; Discussion, pp. 60–70. 21 refs.

Four-Rotor Helicopter. Howard Levy. *The Aeroplane*, June 29, 1956, pp. 612–614. Description of the Convertawings, Inc., projected aircraft which will be produced as a large-capacity vehicle and has been designed to meet the requirements of effectiveness in all phases of short- and medium-haul transportation, safety, economy, stability, and operational adaptability. The basic layout consists of four rotors in tandem pairs supported on booms.

Report on the Rotodyne; The World's Most Versatile Large Helicopter. *Flight*, Aug. 17, 1956, pp. 244, 245.

Where the Rotodyne Scores. *The Aeroplane*, Aug. 17, 1956, pp. 208–208c. Design, propulsion, and performance characteristics of the Fairey Rotodyne.

Der Leistungsstand der Drehflügler. W. Just. *Luftfahrttechnik*, May 15, 1956, pp. 78–87. In German. Appraisal of design, aerodynamic performance, and applications of helicopters.

A Study for Optimum Conditions of Gyrodyne Type Rotary Wing. Masato Hirotsu. *J. Japan Soc. Aero. Eng.*, July, 1956, pp. 168–175. Analysis for determining the optimum condition in which a gyrodyne can fly faster than a helicopter or autogiro.

The Aerodynamics of the Helicopter in Forward Flight. E. N. Brailsford. *J. RAeS*, Aug., 1956, pp. 523–542. 16 refs. Solution for aerodynamic derivatives using the strip theory. Expressions for the determination of the rotor attitude are derived for obtaining a solution of the performance equation. A refined version of the Glauert energy solution is used for performance estimation.

Static-Thrust Measurements of the Aerodynamic Loading on a Helicopter Rotor Blade. John P. Rabbott, Jr. *U.S., NACA TN 3688*, July, 1956. 22 pp. Experimental investigation to obtain the chordwise pressure distributions at five spanwise stations on a 15-ft-diameter helicopter rotor blade in static thrust for a tip speed range of 400 to 500 ft./sec. and disc loads of zero to about 2.5 lbs./ft.^{2}, and to compare the measured spanwise loading with a simple theoretical loading modified by an approximate correction for a finite number of blades.

The Promise of Helicopter Transportation. Raymond Sawyer. *AHS Newsletter*, July, 1956, pp. 3–7. Developmental review and discussion of the potential helicopter market in the need for rapid local transportation.

Safety

Model Ditching Investigation of a Jet Transport Airplane with Various Engine Installations. William C. Thompson. *U.S., NACA RM L56G10*, Aug. 20, 1956. 27 pp. Includes examination in the Langley tank no. 2 of various conditions of damage, engine installations, landing procedure, and speed, using data obtained from visual observation, acceleration records and motion pictures.

Some of the Problems Associated with Aircraft Salvage Operations. I. K. J. Anderson. *J. SLAE*, June, 1956, pp. 3–17. Discussion in terms of economic advisability, preparation, salvage methods, and equipment.

Space Travel

U.S. Earth Satellite Programme for the International Geophysical Year. *The Engr.*, Aug. 17, 1956, pp. 247–249. Discussion of the IGY program including rocket design, satellite orbit, and measurements to be made by the satellite.

The Scientific Value of Artificial Satellites. Fred L. Whipple. *J. Franklin Inst.*, Aug., 1956, pp. 95–110. Review of plans for the launching, velocity, size, orbit, and means of observation of satellites, and discussion of expected data to be relayed by them, particularly in regard to astronomy, the composition of space and the earth's atmosphere, the behavior and the effects of meteors and cosmic rays, navigation, meteorology, and cartography.

Einige Probleme der Raketenentwicklung. Glauco A. Partel. *Weltraumfahrt*, Aug. 1, 1956, pp. 72–76. In German. Discussion of problems encountered in the development of satellite vehicles, with an analysis of satellite dynamics, fuel capacity, and the location of the take-off area.

Structures

The Relationship Between Load Spectra and Fatigue Life. Bo Lundberg and Sigge Eggwertz. *Sweden, Flygtekniska Försöksanstalten, FFA Medd. 67*, 1956. 32 pp. 24 refs. Development of methods to correlate or evaluate fatigue lifetimes using the cumulative damage theory or program testing.

Inequalities for Eigenvalues of Supported and Free Plates. L. E. Payne. *U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN 75 (AFOSR TN 56–281)*, June, 1956. 25 pp. 15 refs. Derivation of certain isoperimetric inequalities for the eigenvalues in the classical vibration and buckling problems in supported and free plates.

Elastoplastic Thick-Walled Tubes of Work-Hardening Material Subject to Internal and External Pressures and to Temperature Gradients. D. R. Bland. *J. Mech. & Phys. Solids*, Aug., 1956, pp. 209–229.

On the Elastic Failure and the Buckling of a Column Under Eccentric Loads. Shosaburo Negoro. *Kyushu U., Rep. Res. Inst. Appl. Mech.*, Oct., 1955, pp. 41–56. Analysis, using Sunatani's buckling theory and assuming the columns to be prismatic bars of uniform cross section hinged at both ends, to determine whether elastic failure occurs when the greatest skin stress in the column reaches the stress at the yield point of the material.

Double Shear Strength of B.S.L.69 Snap Head Rivets in L.72 and L.73 Aluminium Alloy Sheet. D. Howe. *Coll. of Aeronautics, Cranfield, Note 50*, July, 1956. 9 pp. Results of tests on single and double shear riveted joints indicating that, at high bearing stresses, the bearing shear stress in the double shear joint falls below that of the single joint having the same nominal strength.

Investigations into a Photoelastic Method for Direct Measurements of Surface Strains in Metal Components. J. R. Linge. *Coll. of Aeronautics, Cranfield, Rep. 97*, Feb., 1956. 55 pp. 37 refs. Includes description of the technique which consists of an examination of surface strains with optically sensitive materials bonded to the component and of an analysis of the photoelastic pattern produced under load by means of polarized light reflected from the surface of the metal.

Nonlinear Minimum-Weight Design of Planar Structures. Louis G. Vargo. *J. Aero Sci.*, Oct., 1956, pp. 956–960. Development of a method for determining the minimum-weight, fully plastic moments of a planar structure subject to a set of concentrated loads.

Bars & Rods

The Plastic Yielding of Shallow Notched Bars Due to Bending. A. P. Green. *J. Mech. & Phys. Solids*, Aug., 1956, pp. 259–268. Modification of plane strain solutions for notched bars in order to consider a shallow notch where plastic deformation extends to the notched face.

Dinamicheskii Metod Issledovaniia Ustoichivosti Szhatogo Sterzhnia. K. S. Deineko and M. Ia. Leonov. *Prikl. Mat. i Mekh.*, Nov.-Dec., 1955, pp. 738–744. In Russian. Development of a dynamic method for studying the stability of a compressed beam.

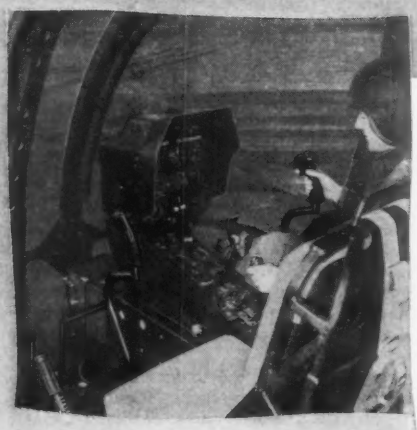
Cylinders & Shells

On the Nonlinear Buckling of Shallow Spherical Domes. Edward L. Reiss. *J. Aero. Sci.*, Oct., 1956, pp. 973, 974. Review of the Kaplan and Fung experimental and theoretical results and extension of these results by solving their equations by power-series expansions using slightly different parameters.

Das Additionstheorem der Vergleichspannungen nach der Gestaltänderungsenergie-Hypothese und die Berechnung von Vergleichspannungen in Hohlzylindern. E. Ulrich. *Forschung Gebiete Ing., Ausg. A*, No. 4, 1956, pp. 123–128. In German. Derivation of a law of addition for comparative stresses according to the hypothesis of the energy of deformation and its application to hollow cylinders.

Lange Zylinderschale mit nicht achsensymmetrischer Randbelastung durch Kräfte in Zylinder-Längsrichtung. G. Sonntag. *Forschung Gebiete Ing., Ausg. A*, No. 4, 1956, pp. 129–133. In German. Theoretical investigation of long cylindrical shells loaded in longitudinal direction at one end. Results

KAMAN HOK-1



The Helicopter You FLY LIKE A PLANE...

Pilots who have never been in a helicopter before are amazed at the ease with which the Kaman HOK-1 can be flown. Any pilot familiar with fixed wing aircraft can fly the HOK-1 and fly it well.

The **KAMAN** *Aircraft Corporation*

BLOOMFIELD, CONNECTICUT, U.S.A.

of a numerical evaluation of the exact solution, valid for the cylindrical shell assumed rigid to bending, indicate that the damping of the longitudinal stresses in longitudinal direction can be satisfactorily represented by a simple approximate solution as a function of curvature and wall thickness of the shell and of the load distribution.

Stateczność Powłoki Walcowej Wzmocnionej Żebrami. W. Nowacki and Z. Olesiak. *Rozprawy Inżynierskie* (Warsaw), No. 1, 1956, pp. 3–22. In Polish. Analysis of the buckling problem of a cylindrical shell with longitudinal and transverse ribs using the differential equations of the Vlasov engineering theory of shells.

Cienkościenna Powłoka Toroidalna Obciążona Równomiernym Ciśnieniem. Aleksander Kornecki. *Rozprawy Inżynierskie* (Warsaw), No. 1, 1956, pp. 119–172. 19 refs. In Polish. Method for the approximate computation of stress and strain components in a thin-walled toroidal elastic shell of circular cross section, limited by two parallels and loaded with uniform pressure.

Opredelenie Kriticheskogo Davleniia Obolochki, Ocherchennoi po Odnopolostnomu Giperboloidu. N. A. Alumial. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1956, pp. 223–235. In Russian. Determination of the critical pressure of a shell designed according to the single-cavity hyperboloid.

Elasticity & Plasticity

Physical & Metallurgical Aspects of Creep. I—Physical Considerations. L. A. Phelps. *Metal Treatment*, Aug., 1956, pp. 311–314. 23 refs. Review of various theories on the mechanism of creep, including transient, quasi-viscous, and tertiary creep.

Creep Relaxation for Combined Stresses. J. E. Griffith and Joseph Marin. *J. Mech. & Phys. Solids*, Aug., 1956, pp. 283–293. 12 refs. Development of a theory for predicting stress relaxation-time relations for creep in the case of combined stresses based on an assumed constant stress-creep-time relation.

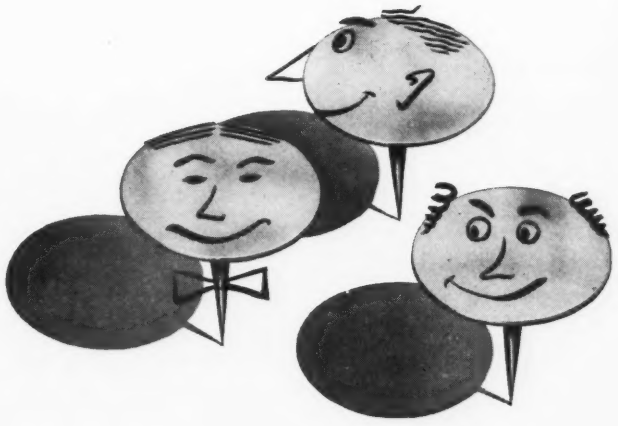
Uprugo-Plasticheskie Deformatsii Tel pri Povtornikh Nagruzheniiakh. V. V. Moskvitin. *Prikl. Mat. i Mekh.*, Nov.-Dec., 1955, pp. 714–723. In Russian. Study of elastoplastic deformations of beams subjected to cyclic loading and of repeated oblique loading of shells under internal pressure.

Ob Uravneniiakh Plasticheskogo Techeniia v Pogranichnom Sloe. V. V. Sokolovskii. *Prikl. Mat. i Mekh.*, May-June, 1956, pp. 328–334. In Russian. Study of plastic flow in the immediate vicinity of the boundary curve.

Estudio Sobre las Deformaciones de una Lámina de Espesor Variable. Enrique L. Samatan. (*Rev. Fac. Cienc. Fisicomat.*, Jan., 1956, pp. 58–69.) *La Plata, U. Nac. Fac. Cienc. Fisicomat. Dept. Aero., Pub. 59*, 1956. 12 pp. In Spanish. Study of deformation in plates of variable thickness.

K Ispol'zovaniiu Lineinoi Tenzornoi Sviazi v Plastichnosti. D. D. Ivlev. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1956, pp. 289–292. In Russian. Analysis of data

Our Engineers are sharp as tacks



and they hold down pretty good jobs

Engineers are a big part of the picture at Kaman. They realize the importance of their job, and take pride in doing it and doing it well.

Intelligence, imagination and hard work are required of every Kaman engineer. The ability to channel these qualities toward a productive end has earned great respect for the Kaman engineering staff. It is, of course, apparent in the many pioneering steps taken by Kaman in the helipcoter field, as well as in the field of research and development, where Kaman is working on many classified projects.

Naturally, men with outstanding ability expect to be rewarded, and Kaman obliges with top level salaries, unlimited opportunities and the satisfaction of working where progressive thinking is being applied every day.

If you'd like to sail along at a faster clip, take a new tack — check the position you can fill and return the coupon with a brief resume, if possible, *now*. Have we made our point?

KAMAN

THE KAMAN AIRCRAFT CORP.
61 Old Windsor Road
Bloomfield, Conn.

Att: W. M. Tynan, Administrative Engineer

Name_____
Address_____
City_____
State_____
Home Phone_____

☐ Aerodynamics
☐ Design Drafting & Layout
☐ Dynamics
☐ Electrical Design & Layout
☐ Electronics
☐ Liaison
☐ Mechanical Design
☐ Preliminary Design & Research
☐ Stress Analysis
☐ Systems Development
☐ Structural Design
☐ Test & Development
☐ Thermodynamics
☐ Weights

obtained on the linear tensorial relationship between the deviation functions of stresses and deformations, subject to experimental verification.

A Note on the Deformable Region in a Rigid-Plastic Body. J. F. W. Bishop, A. P. Green, and R. Hill. *J. Mech. & Phys. Solids*, Aug., 1956, pp. 256–258. Methods of determining the deformable region are presented, and an example of indentation is considered under conditions of plane strain, plane stress, and axial symmetry.

On the Problem of Uniqueness in the Theory of a Rigid-Plastic Solid. I. R. Hill. *J. Mech. & Phys. Solids*, Aug., 1956, pp. 247–255. Theoretical analysis of a rigid-plastic system.

On the Propagation of Elastic Waves in Aeolotropic Media. III—Media of Cubic Symmetry. G. F. Miller and M. J. P. Musgrave. *Proc. Royal Soc. (London), Ser. A*, Aug. 2, 1956, pp. 352–383. Application of a previously derived general analytical method to the determination of velocity, inverse and wave surfaces of a medium of cubic symmetry.

Compressive and Torsional Buckling of Thin-Wall Cylinders in Yield Region. Appendix A—**Plasticity Considerations.** Appendix B—**Equilibrium Considerations; Elastic Buckling.** Appendix C—**Axial Compressive Buckling of a Long Cylinder.** Appendix D—**Torsional Buckling of a Long Cylinder.** George Gerard. *U.S., NACA TN 3726*, Aug., 1956. 42 pp. 22 refs.

O Sviazi Mezhdu Napriazheniiami i Deformatsiiami v Nelineinoi Teorii Uprugosti. L. A. Tolokonnikov. *Prikl. Mat. i Mekh.*, May-June, 1956, pp. 439–444. In Russian. Study of the relationship between stresses and deformations in the nonlinear theory of plasticity.

K Teorii Prostogo Deformirovaniia Plasticheskikh Tel. D. D. Ivlev. *Prikl. Mat. i Mekh.*, Nov.-Dec., 1955, pp. 734, 735. In Russian. Generalization of the Il'iushin theorem of simple loading in the case of dependence σ_i—e_i, presented as a polynomial. It is shown that, for any joint system of deformation of a given body for such a dependence, there is a single complex loading, during which a simple deformation occurs within the body. It is also shown that such loading is practically impossible.

Sprężysto-Plastyczna Grubościenna Powłoka Kulista z Materiału Niejednorodnego, Poddana Działaniu Ciśnienia Wewnętrznego i Zewnętrznego. W. Olszak and W. Urbanowski. *Rozprawy Inżynierskie* (Warsaw), No. 1, 1956, pp. 23–41. In Polish. Study of thick-walled elastoplastic spherical shells of nonhomogeneous material, subjected to internal and external pressure.

Symposium on the Plastic Theory of Structures. IV—Plastic Design and Thermal Stresses. William Prager. **V—Dynamic Loading and Impact.** P. S. Symonds. *Brit. Welding J.*, Aug., 1956, pp. 355–361. Discussion of the influence of cycles of thermal stress on the load-carrying capacity of an elastic, perfectly plastic structure, taking into account both single-loading and repeated-loading cycles and assuming temperature changes to be either completely independent of loads or partly dependent on them. A geometrical representation is given for a simple example, and the results are extended to more complex structures.

Thermal Stress

Fundamental Principles and Theorems of Thermo-Elasticity. W. S. Hemp. *Aero. Quart.*, Aug., 1956, pp. 184–192. Outline of foundations of thermoelasticity and derivation of generalizations of the usual variational theorems used in structural analysis.

Thermal Stresses and Deformations in Beams. Samuel Levy. (*IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Preprint 576.*) *Aero. Eng. Rev.*, Oct., 1956, pp. 62–70. Derivation of general formulas for computing the thermal stresses and curvature in a long beam when the rise in temperature at any location in the beam cross section is given and when the coefficient of expansion and Young's modulus are known functions of temperature.

Odkształcenia i Naprężenia Termiczne w Płytach na Sprężystym Podłożu. Zygmunt Thrun. *Rozprawy Inżynierskie* (Warsaw), No. 1, 1956, pp. 71–86. In Polish. Application of the method of finite differences to the determination of thermal stresses and strains in plates.

O Poziomym Oddziaływaniu Sprężystego Podłoża na Płyty Poddane Działaniu Zmian Temperatury. Zygmunt Thrun. *Rozprawy Inżynierskie* (Warsaw), No. 1, 1956, pp. 87–97. In Polish.

ULTRA-DEPENDABLE
ROTARY SELECTOR SWITCH
—built to eliminate replacement expense
MASON
Heavy Duty Series
3 to 12 position
Available in single section up to six sections, 1 to 3 poles each section. Continuous duty rating: 45 Amps. max. Revolutions at 25 Amps. resistive: 20,000; at 15 Amps. inductive: 25,000.
Arcing is minimized by the extra-fast, double break, self-detenting operation.
This Mason switch eliminates the need for relays. It has a low operating torque, and is suitable for use with rotary solenoids. You get a wide choice of selector circuits. High pressure on the rolling contact provides excellent vibration characteristics. Unit meets all military environment tests.
write for details
MASON
MASON ELECTRIC CORP.
3839 Verdugo Rd., Los Angeles 65, Calif.
switches designed for reliability

Derivation, for a plate resting on an elastic foundation, of differential equations for deflection, bending and twisting moments, and shear and normal forces.

Thermodynamics

Ob Usloviakh Vozniknoveniia Konvektsii v Binarnoi Smesi. B. A. Vertheim. *Prikl. Mat. i Mekh.*, Nov.-Dec., 1955, pp. 745–750. In Russian. Study of some convection phenomena occurring in binary mixtures.

Ob Ustoichivosti Neravnomerno Nagretoi Zhidkosti v Vertikal'nom Ellipticheskom Tsilindre. E. M. Zhukhovitskii. *Prikl. Mat. i Mekh.*, Nov.-Dec., 1955, pp. 751–755. In Russian. Study of the conditions of heat-convection occurrence in vertical elliptical cylinders heated at the bottom. An approximate solution is obtained using the Galerkin method.

Combustion

Kinetics of the Combustion of Carbon at High Temperatures and Low Pressures. Xavier Duval. (*Ann. Chim.*, Nov.-Dec., 1955, pp. 903–967.) *Gt. Brit., RAE Lib. Transl. 573*, May, 1956. 55 pp. 56 refs. Study of the kinetics of the reaction between carbon and oxygen at pressures between 5×10^{-5} and 3×10^{-3} mm. Hg, and at temperatures ranging from 1,100° to 2,200°K.

Ancora su Questioni di Similitudine Riguardanti l'Irraggiamento Termico delle Fiamme. Cesare Codegone. (*Atti Acad. Sci. Torino*, Vol. 90, 1955–1956.) *Torino Polytech. Inst., Aero. Lab., Monograph 376*, 1955. 7 pp. In Italian. Evaluation of experimental data on thermal radiation of flames.

Heat Transfer

Heat Transfer from a Rotating Disk. E. C. Cobb and O. A. Saunders. *Proc. Royal Soc. (London), Ser. A*, Aug. 2, 1956, pp. 343–351. 11 refs. Experimental investigation for obtaining accurate measurements over a range of speeds giving purely laminar conditions at one extreme and turbulent conditions over most of the disc at the other extreme. Includes measurements of the velocity and temperature profiles for both the laminar and turbulent conditions, and a discussion of the relation between heat transfer and friction torque.

Conduction of Heat in an Infinite Region Bounded Internally by a Circular Cylinder of a Perfect Conductor. J. C. Jaeger. *Australian J. Phys.*, June, 1956, pp. 167–179. 12 refs.

Thermal and Electrical Conductivities of Iron, Nickel, Titanium, and Zirconium at Low Temperatures. W. R. G. Kemp, P. G. Klemens, and G. K. White. *Australian J. Phys.*, June, 1956, pp. 180–188. 11 refs.

Ob Odnoi Zadache Teploprovodnosti dlia Dvukh Sred. D. L. Shil'krut. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1956, pp. 284–288. In Russian. Study of the thermodynamic behavior of air over a flat surface under the influence of a heat source.

La Similitudine Termina Negli Scambiatori di Calore Rotanti. Federico Filippi. (*Atti Acad. Sci. Torino*, Vol. 90, 1955–1956.) *Torino Polytech. Inst., Aero. Lab., Monograph 373*, Nov. 23, 1955. 10 pp. 10 refs. In Italian. Study of the thermal similarity of rotating heat exchangers considered as porous discs, with derivation of differential equations for the internal temperature distribution and with definition of nondimensional parameters governing this phenomenon.

Configurazione Ottima di uno Scambiatore di Calore Rotante di Data Efficacia della Rigenerazione. Federico Filippi. (*Atti Acad. Sci. Torino*, Vol. 90, 1955–1956.) *Torino Polytech. Inst., Aero. Lab., Monograph 380*, 1956. 19 pp. In Italian. Application of a previously developed theory on thermal similarity of rotating heat exchangers to the determination of the fact that two exchangers of the specified type, having different operating conditions, give equal results for regeneration efficiency.

Compressibility Factor, Density, Specific Heat, Enthalpy, Entropy, Free-Energy Function, Viscosity, and Thermal Conductivity of Steam. Lilla Fano, John H. Hubbell, and Charles W. Beckett. *U.S., NACA TN 3273*, Aug., 1956. 61 pp. 43 refs.

Vertical Take-Off Aircraft

Lift on a Wing in a Propeller Slipstream as Related to Low-Speed Flight. Scott Rethorst. (*IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 643.*) *Aero. Eng. Rev.*, Oct., 1956, pp. 42–48.

Water-Borne Aircraft

Water Tunnel Tests of NACA 4412 and Walchner Profile 7 Hydrofoils in Noncavitating and Cavitating Flows. Robert W. Kermeen. *CIT Hydrodynamics Lab. Rep. 47-5*, Feb., 1956. 73 pp. Tests on two hydrofoils with comparison of results to experiments performed in wind tunnels and other water tunnels. Includes description of experimental setup, procedure, and methods of data reduction.

Change of Address

Please notify the Institute of the Aeronautical Sciences, 2 E. 64th St., New York 21, N.Y., when you change your mailing address.

Notification of the change should be received 30 days in advance of publishing date to ensure receipt of every issue of the *Journal* and *Review*.

The Forces and Moments Acting on a Tandem Hydrofoil System in Waves. Paul Kaplan. *Stevens Inst. Tech. Exp. Towing Tank Rep. 506*, Dec., 1955. 37 pp. 19 refs. Theoretical investigation to derive expressions for the forces and moments for both head and following seas. Includes experimental verification.

A Source Solution for Short Crested Waves. R. C. MacCamy. *U. Calif. Inst. Eng. Res., Ser. 61/I5*, Apr., 1954. 19 pp. Derivation of Green's function for the boundary-value problem arising in the diffraction of short-crested waves around obstacles of bounded cross section, and application of the function to two problems: the production of waves by a moving partition and the reflection from a horizontal strip.

Wind Tunnels & Research Facilities

Centro di Studio per la Dinamica dei Fluidi; Attività Svolta Durante l'Anno 1955. Modesto Panetti. (*Ricerca Sci.*, Feb., 1956.) *Torino Polytech. Inst., Aero. Lab., Monograph 374*, Feb., 1956. 9 pp. In Italian. Description of a facility for fluid dynamics research and of its activities during the year 1955.

A 36-Inch Variable Pressure Water Tunnel. W. F. Brownell. *U.S., Navy Dept., David W. Taylor Model Basin, Rep. 1052*, June, 1956. 56 pp. Description of the facility at the David Taylor Model Basin, with design information concerning tunnel components, electric drives, instrumentation, and auxiliary equipment.

A Review of Developments and Research at the Hydromechanics Laboratory of the David Taylor Model Basin, 1953–56. F. R. Todd. *U.S., Navy Dept., David W. Taylor Model Basin, Rep. 1056*, July, 1956. 26 pp. 34 refs. Study of current and projected experimental facilities at the David Taylor Model Basin, and a brief discussion of various research projects which includes studies of planing surfaces for flying boats and hydrofoils.

Mathematical Description of Gas Flow Processes for Control Purposes. G. V. Schwent, W. K. McGregor, and D. W. Russell. *ISA J.*, Aug., 1956, pp. 274–290. Theoretical investigation to determine the dynamic behavior of a wind tunnel used in testing aircraft jet engines, with results presented in the transfer-function form useful for frequency-response and indicial-response studies.

Brief Description of the R.A.E. Intermittent Supersonic Wind Tunnel Plant. K. G. Winter. *Gt. Brit., RAE TN Aero. 2459*, June, 1956. 14 pp.

Note on Strain Gauge Recording Equipment for the R.A.E. Intermittent Supersonic Wind Tunnels. K. G. Winter and E. J. Petherick. *Gt. Brit., RAE TN Aero. 2461*, June, 1956. 12 pp. Description of a simple system for photographing (up to six times per sec.) revolution counters driven from strain-gage balance indicators, and of a proposed system using punched cards.

Wind Tunnel Boasts Centralized Data-Processing Unit. *Ind. Labs.*, Sept., 1956, pp. 48, 49. Description of the system

ANOTHER
EASTERN ROTORCRAFT PRODUCT

The Model MB-1 Cargo Tie-Down for 10,000-lb service supplements ERC's other lines of Tyzem® securing equipment: D-1, 25,000-lb, chain; C-2, 10,000-lb, chain; B-2, 5000-lb, chain; B-1A, 5000-lb, cable; MC-1, 5000-lb, web; and A-1a, 1250-lb, web.

ERC also specializes in the development and manufacture of helicopter mechanical assemblies, transmission test stands, cargo sling nets and release hooks.

EASTERN ROTORCRAFT
CORPORATION
DOYLESTOWN, PENNA.

how to
complete coax assemblies successfully
MICRODOT®
pioneer in micro-miniature circuitry, offers complete assemblies in any quantity. Write today and describe the coax solutions you require. With Microdot* cables and over 300 Connectors, our engineers can quickly and economically supply guaranteed solutions giving you superior environmental performance and operating characteristics.
Actual Size! Hermetic Seal insulated Feed-Through.
MICRODOT
1826 FREMONT ST.
SO. PASADENA, CALIF.

which is part of a data-processing center connected directly to a 10- by 10-ft., 2 to 35 Mach Number tunnel and four other major research installations on the grounds of the NACA Lewis Flight Propulsion Laboratory at Cleveland Airport, and whose results, which are convertible to graphical form by automatic plotters, can be read on paper tape printed in the tunnel control room on automatic typewriters.

Automatic Plotting of Wind Tunnel Force Data. Stanley E. Newell. *Boeing Rep. D-17292*, Oct. 14, 1955. 26 pp. Description of a small, special-purpose computer, simple in design and operation, and capable of producing results of required accuracy during the running of wind-tunnel tests.

Compressors for High-Speed Wind Tunnels. Appendix I—**The Influence of Prerotation Vanes on the Torsional Vibration of Wind Tunnel Fan Blades.** Appendix II—**The Influence of Prerotation Vanes on the Lateral Vibration of Wind Tunnel Fan Blades.** Andrew A. Fejer and James Clark. *NATO AGARDograph 14*, Jan., 1956. 216 pp. 119 refs. Analysis of compressor systems for wind tunnels designed for continuous operation.

Studies on Wake Vortices. II—Experimental Investigation of the Wake Behind Cylinders and Plates at Low Reynolds Numbers. Sadotoshi Taneda. *Kyushu U., Rep. Res. Inst. Appl. Mech.*, Oct., 1955, pp. 29–40. 10 refs. Photographic investigation over a Reynolds Number range of 0.1–2,000 to determine the critical Reynolds Numbers at which (a) twin vortices appear at the rear of a circular cylinder and (b) oscillation of the wake behind such a cylinder begins; (c) to verify the solutions of Navier-Stokes equations even in the case of $R = 40$; (d) to observe the wake behind flat plates parallel to the direction of motion; and (e) to develop and apply a new method for clarifying the structure and nature of the von Kármán vortex street.

A Note on the China-Film Technique for Boundary Layer Indication. R. J. Stalker. *J. RAeS*, Aug., 1956, pp. 543, 544. Investigation to determine the process by which the patterns form and to establish the aerodynamic meaning of the flow lines of the pattern.

Loads on a Model During Starting and Stopping of an Intermittent Supersonic Wind Tunnel. K. G. Winter and C. S. Brown. *Gt. Brit., RAE TN Aero. 2453*, May, 1956. 17 pp. Measurements of loads at Mach Numbers 2.00 and 2.48.

Some Comments on High-Lift Testing in Wind Tunnels with Particular Reference to Jet-Blowing Models. Appendix I—**Suitable Location of Surface Pressure Points.** Appendix II—**Details of Air-Feed, R. A. E. Half-Model.** Appendix III—**Details of Air-Bearing Connectors; N.P.L. Models (Suitable for Lift, Drag and Pitching Moment Readings).** Appendix IV—**Suggestions for the Size of End-Plates.** Appendix V—**Formulae for Momentum Coefficient, $C\mu$, and Notes on Accuracy of Measurement.** A. Anscombe and J. Williams. *Gt. Brit., RAE TN Aero. 2460*, June, 1956. 30 pp.

Over 85% of the torque wrenches used in industry are
STURTEVANT
TORQUE WRENCHES
Read by Sight, Sound or Feel.
● Permanently Accurate
● Practically Indestructible
● Faster—Easier to use
● Automatic Release
● All Capacities
in inch grams...inch ounces...inch pounds ...foot pounds
(All sizes from 0-6000 ft. lbs.)
TORQUE MANUAL
Every manufacturer, design and production man should have this valuable data. Sent upon request.
P.A. STURTEVANT CO
ADDISON [QUALITY] ILLINOIS

ATTENTION ADVERTISERS

YOUR BEST INVESTMENT IN ENGINEERING READERSHIP IS AERONAUTICAL ENGINEERING REVIEW

The ONLY magazine serving the specialized interests of professional engineers and design project teams in the aviation industry.

Aeronautical Reviews — BOOKS

AERODYNAMICS

Flow of Gases Through Porous Media. P. C. Carman. London, Butterworths Scientific Publications; New York, Academic Press Inc., 1956. 183 pp., diagrs., tables. $6.00.

This text provides an integrated and quantitative account of the flow processes involved when gases flow into or through fine-pored media. It presents a connected account of the current knowledge on the subject, both theoretical and practical, rather than indulging in specific technical applications. The subject is approached from the viewpoint of the Kozeny theory; its limitations are fully discussed for consolidated media for high porosities and for relative permeability, with particular attention to the question of pore size distribution. It is extended to cover the transition to Knudsen flow, and, in the last chapter, the transition from viscous to turbulent flow. Its application to the permeability method for measurement of surface of powders is fully described. In addition, recent work on surface diffusion and capillary flow of adsorbable gases in fine-pored systems is reviewed. A chapter on the use of porous media for gas separations includes a discussion of gas chromatography. The appendixes include an author index, a subject index, and a table of symbols used in the text. The author is Chief Research Officer, National Chemical Research Laboratory, South African C.S.I.R.

COMPUTERS

Digital Differential Analyzers; An Applications Manual for Digital and Bush Type Differential Analyzers. George F. Forbes. 3rd Ed. Pacoima, Calif., G. F. Forbes, 1956. 182 pp., diagrs., tables. $7.50.

For the mathematician, engineer, or researcher as an aid in the utilization of the equipment and personnel of a DDA or Bush installation. The second edition was published in 1955, and the text is included in the present edition along with additional material. Most of the material deals with the mathematical theory of the problem rather than with specific case runs on the machine. The author is Senior Engineer at Litton Industries.

DATA PROCESSING

Proceedings: Automatic Data Processing Conference, Sept. 8–9, 1955. Edited by Robert N. Anthony. Boston, Graduate School of Business Administration, Harvard University, 1956. 194 pp. $3.50.

Contents: (1) Automatic Data Processing Methods, T. F. Bradshaw. (2) Principles of Electronic Data Processing, Anthony Oettinger. (3) Administrative Problems of the Investigation Phase, Peter B. Laubach. (4) Problems of Decentralization, Frank H. Muns. (5) Problems of Centralization, James W. Pontius. (6) An Evaluation of Electronic Data Processing Equipment, Samuel N. Alexander. (7) The Role of Special Purpose Equipment, Kenneth E. Iverson. (8) Selecting an Application for Mechanization, John D. Dillon, Janus O. Dyal, and Byron O. Marshall, Jr. (9) Case Study—Order Processing and Production Planning, Edward L. Wallace. (10) An Application to Payroll, G. M. Sheehan. (11) Operations Research—Its Relationship to Data Processing, Russel L. Ackoff. (12) What to Expect from Operations Research, M. L. Hurni.

DICTIONARIES

The International Dictionary of Physics and Electronics. Walter C. Michels, Senior Editor. Princeton, N.J., D. Van Nostrand Co., Inc., 1956. 1,004 pp., diagrs. $20.

An international group of scientists and educators has prepared this dictionary giving definitions of the principal terms used in classical and modern physics. The purpose has been to provide a general reference work in physics useful also to those in other fields, such as chemistry, biology, engineering, and technology. The attempt at so generalized a program has resulted in some arbitrary decisions and compromises. One of the compromises concerns units. To avoid confusion, the hundred or more physical measurement systems have been reduced to the measurement of mechanical, thermal, or electromagnetic quantities or to some combination of these. Whenever a choice exists as to the system of units in which a quantity may be defined, the Dictionary has either given two or more definitions, specifying the systems in which each is appropriate, or has stated the dimensions of the quantity in such a way that the definition may be modified when a different system is employed. Descriptions of the three systems of units which are used are treated as part of the introduction. The treatment comprises terms of pure science as well as those of its applications: laws, relationships, equations, basic principles and concepts, and the most widely used instruments, apparatus, and their components. Wherever possible, all definitions have been included which have been established or recommended by authority. There are over 300 diagrams and 14,000 terms which cover some 16 major subjects including: mechanics, heat, and thermodynamics; low-temperature physics; the properties of gases, liquids, and solids; acoustics; optics; electricity; electronics; nuclear physics; mathematical physics; and representative topics in relativity. There are no separate tables for signs, symbols, or abbreviations; they are contained in the body of the text with the symbols that are given being found under their Romanized equivalent—i.e., < > is found under Inequality. For those of moderate mathematical background, both explicit and discursive statements and entries are given as well as definitions of the more common mathematical terms of present-day physics.

The Condensed Chemical Dictionary. Completely Revised and Enlarged by Arthur and Elizabeth Rose. 5th Ed. New York, Reinhold Publishing Corporation, 1956. 1,200 pp. $12.50.

A reference volume providing ready access to essential data on chemicals and other substances used in manufacturing and research and to terms in general use in chemistry and the process industries. Includes data on the chemical and physical properties of chemicals and raw materials; current information on containers, shipping regulations, and safety instructions; and new uses of chemicals in nuclear energy, chemotherapy, and other fields. The many cross references help clarify the confusion brought on by chemicals and their synonyms. Entries are in straight alphabetical arrangement with numbers ignored for alphabetizing purpose. Thus, *3F bomb* is alphabetized as "f-b-o-m-b." The introduction contains a directory of 355 contributing manufacturers plus information on trade-marks, transportation of explosives and other dangerous materials, and safety information-warnings and labels. A previous edition of the work appeared in 1950 under the editorship of Francis M. Turner. This new edition contains almost twice the number of pages and includes over 30,000 entries.

DRAWING

A Manual of Engineering Geometry and Graphics for Students and Draftsmen. Hollie W. Shupe and Paul E. Machovina. New York, McGraw-Hill Book Co., Inc., 1956. 347 pp., diagrs., tables. $5.25.

In addition to the text material needed in engineering geometry, this book provides material for a more general coverage of graphic solutions. The material covered includes the fundamentals of orthographic projection and their use in the solution of the geometric problems of line and surface relationships, and vectors; and functional scales and their applications in conversion and sliding scales, alignment charts, curve fitting, and graphic calculus. In addition to the usual bibliography, there is a bibliography of Visual Aids—film material. The author is Professor of Engineering Drawing, Ohio State University.

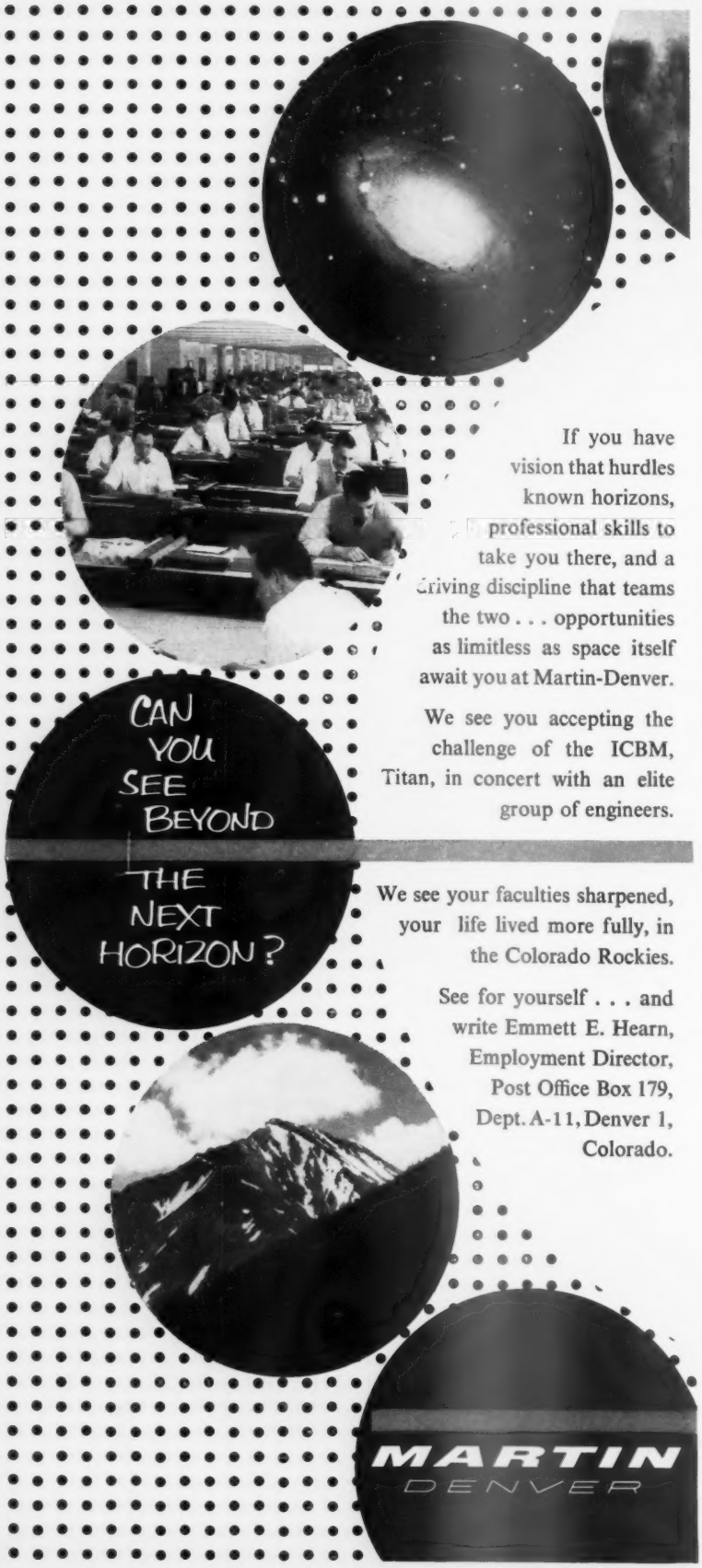
ELECTRONICS

Vacuum-Tube Circuits and Transistors. Lawrence Baker Arguimbau and Richard Brooks Adler. New York, John Wiley & Sons, Inc., 1956. 646 pp., diagrs. $10.25.

A textbook which bases its approach on fundamental principles rather than on descriptive study. The authors are primarily concerned with circuitry rather than with the physics of the electronic devices used in the circuits. There are two chapters, however, which contain enough descriptive matter to make previous knowledge of vacuum electronics nonessential. Considerations of the transistor, though, has necessitated attention to the physics behind the devices. Formalized mathematics is held to a minimum, quantum mechanics is not used, and practically no mention is made of gaseous-conduction devices. Though not termed a revision, the book is an extension of

For information on IAS Library Services, see page 119

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.


If you have vision that hurdles known horizons, professional skills to take you there, and a driving discipline that teams the two . . . opportunities as limitless as space itself await you at Martin-Denver.
We see you accepting the challenge of the ICBM, Titan, in concert with an elite group of engineers.
CAN YOU SEE BEYOND THE NEXT HORIZON?
We see your faculties sharpened, your life lived more fully, in the Colorado Rockies.
See for yourself . . . and write Emmett E. Hearn, Employment Director, Post Office Box 179, Dept. A-11, Denver 1, Colorado.
MARTIN
DENVER

Vacuum-Tube Circuits which appeared in 1948 and which treated transistors in briefer fashion. L. B. Arguimbau is associated with the McIntosh Library at Binghamton, N.Y., and R. B. Adler is Associate Professor of Electrical Communications, M.I.T.

Contents: Radio Communications. Diodes and Rectifiers. Triodes, Pentodes, and Linear Amplifiers. Transistors (Principles). Transistors (Linear Amplifiers). Transient Response of Video Amplifiers. Amplitude Modulation and Tuned Amplifiers. Power Amplifiers. Oscillators. Inverse Feedback. Amplitude Modulation. Frequency Modulation. Television. Transit Time. Noise. Index.

Electronics and Electron Devices. Arthur Lemuel Albert. 3rd Ed. New York, The Macmillan Company, 1956. 582 pp., diagrs., tables. $8.00.

This textbook for college and university courses appeared in its 1938 and 1947 editions under the title *Fundamental Electronics and Vacuum Tubes*. The presentation of material is a balance between theory and illustrative applications. Almost entirely rewritten, much of the descriptive matter of other earlier editions has been discarded for new material. Added features of the book are a chapter on Magnetic Amplifiers and a chapter on Wave-Shaping and Control Circuits which covers differentiating, integrating, limiting, clipping, multivibrator, and similar circuits. References, review questions, and problems are included at the end of each chapter. The author is Professor of Communication Engineering, Oregon State College.

Introduction to UHF Circuits and Components. Milton S. Kiver. New York, D. Van Nostrand Company, Inc., 1955. 408 pp., illus., diagrs. $7.50.

The information contained herein is broad and qualitative. Consequently, the book should have a wide audience—the technician, the student, the amateur, and the professional engineer. The author's purpose has been to point out the underlying equality of all radio, whatever the frequency. The concepts of ultra-high frequency circuits are presented as logical outgrowths of the more familiar low-frequency equipment. The many component problems relating to the generation, transmission, radiation, and reception of UHF signals are dealt with. Discussions concern UHF television, microwave relay stations, UHF receivers and transmitters, resnatron and traveling-wave tubes, klystrons and magnetrons, transmission lines, wave guides, UHF antennas, and measurements.

EQUIPMENT, HYDRAULIC

A Treatise on Applied Hydraulics. Herbert Addison. 4th Ed. London, Chapman & Hall, Ltd.; New York, John Wiley & Sons, Inc., 1954. 724 pp., illus., diagrs., tables. $9.50.

A textbook which limits itself to direct explanations of hydraulic principles with references to more detailed information. Subject matter has been revised and expanded in keeping with the advances in hydraulic engineering that have occurred since the third edition was issued in 1944. The author was formerly Professor of Hydraulics Machines at the Fouad I University, Giza, Egypt.

Contents: (1) Liquids and Their Properties. (2) Liquids at Rest; Static Pressure, etc. (3) Liquids in Motion. (4) Flow Through Orifices and over Weirs. (5) Flow through Closed Conduits. (6) Flow Along Open Channels. (7) Dynamic Pressure of Liquids. (8) Radial and Rotary Motion of Liquids. (9) Pipes and Pipe Systems. (10) Control of Water in Open Channels. (11) Some Other Flow Problems. (12) Hydraulic Machines. (13) Hydraulic Turbines: (1) Construction. (14) Hydraulic Turbines: (2) Performance. (15) Pumping Machinery: (1) Positive Pumps, Water and Gas-Operated Devices, etc. (16) Pumping Machinery: (2) Centrifugal Pumps. (17) Pumping Machinery: (3) Propeller and Screw Pumps. (18) Hydraulic Transmission and Storage of Energy. (19) Hy-

BIW
BOSTON INSULATED WIRE & CABLE CO.

LOOK TO B.I.W. FOR *Leadership*

FLEXIBLE HIGH TEMPERATURE COAXIAL CABLES

GENERALLY THESE CABLES CONFORM TO THE DIMENSIONS AND ELECTRICAL PROPERTIES OF STANDARD COAXIAL CABLES, BUT ARE DESIGNED FOR UNUSUAL SERVICE CONDITIONS IN AIRCRAFT AND ELECTRONIC APPLICATIONS. IN ADDITION, A NUMBER OF VERY SMALL CABLES HAVE BEEN DESIGNED FOR MINIATURE WIRING.

The insulation consists of "teflon" tape applied in a unique manner and sealed from moisture and air. The trade name for this product is "Teflex" which is patented. The nature of the insulation is such that the cable will withstand temperatures as low as −80°F and up to 500°F for long periods of time with very little deterioration in dielectric characteristics. All of these cables, although having the same type of insulation, have various types of outer coverings to be suitable for the various types of service conditions. These coverings are identified in the type number as a suffix: GL—glass braid; MNL—mylar tape and nylon braid; GF—teflon coated glass; GV—teflon tape and glass braid; GGV—same with heavy duty braid; F—sealed teflon.

TYPE NUMBER	CONDUCTOR	O.D. NOMINAL	OHMS IMPEDANCE	CAP./FT mmf	VOLTAGE RATING	CHARACTERISTICS
COX-2FS-011-GL, NL, GV, F	.011" CW	.075"	50	30	750	Low Noise-Flexible
COX-2FX-29-NL, F	7/38 CW	.075	50	30	500	RG-178/U
COX-2FS-22-GL, NL, GV, GGV, F	#22 str.	.125	50	30	2000	Small Flexible
COX-2FS-20-GV, NML, GGF	#20 str.	.180	50	30	2000	Flexible RG-159/U
COX-2FS-032-GV, GF	.032"	.200	50	30	2000	RG-159/U
COX-2FS-16-GV	#16 str.	.325	50	30	3000	Flexible RG-143/4
COX-2FS-13-GV, GGV	#13 str.	.375	50	30	5000	RG-115/U 115A/U
COX-2FS-10-GV	#10 str.	.490	50	30	7000	RG-94A/U
COX-2FS-5-GV	#5 str.	.710	50	30	10000	RG-93/U
COX-3FS-011-GL, NL, GV, F	.011" CW	.090	70	21	1000	Equal to RG-179/U
COX-3FX-26-NL, F	#26 str.	.120	70	21	1000	Miniature
COX-3FS-23-MNL	#23 str.	.200	75	20	2500	Smaller Flex. RG-124/U
COX-3FS-22-GL, MNL, GV, GGV	#22 str.	.170	73	20	2300	Flex. equal RG-124/U
COX-3FS-026-GV	.026 CW	.240	73	20	2300	RG-124/U
COX-4FS-011-GL, NL, GV, F	.011 CW	.125	90	16	1200	Low noise-Flexible
COX-4FX-29-GL, F	#29 str.	.140	90	16	750	Equal to RG-180/U
COX-4FS-016-GL, GF	.016 CW	.200	100	13	500	Equal to RG-62/U
COX-4FS-24-MNL	#24 str.	.240	93	14	2500	Medium voltage
COX-4FS-22-GL, GV, GF	#22 str.	.240	90	16	3000	Low capacity
COX-4FS-026-GV	.026 CW	.240	93	16	3000	Flexible Cables
COX-4FF-023-GF	.023"	.240	93	13	500	Equal to RG-71/U
COX-4FF-026-GV	.026 CW	.240	93	15	500	Equal to RG-62C/U

BOSTON INSULATED WIRE & CABLE CO.
70 BAY STREET · BOSTON 25, MASS.

JOY MANUFACTURING COMPANY

The Joy Manufacturing Company, leaders in mining, construction and industrial equipment, has good job openings for

AERODYNAMICISTS

FOR AERODYNAMIC DESIGN AND ANALYSIS OF FANS, PREPARATION OF DATA AND PERFORMANCE CURVES AND RESEARCH INTO NEW FAN DEVELOPMENTS.

A FINE OPPORTUNITY WITH A RAPIDLY GROWING COMPANY.

Call or submit resumes to:

R. E. Snodgrass
Joy Manufacturing Company
338 South Broadway
New Philadelphia, Ohio

When you write to manufacturers whose advertising appears in the

Aeronautical Engineering Review,

it will be of interest to the companies and of benefit to the Institute if you mention that you saw it in the

Aeronautical Engineering Review

Engineers . . .

MECHANICAL DESIGN

at this Company

MEANS MORE CAREER POTENTIAL

You'll be working on such advanced and stimulating problems as how to develop a gas turbine with a power-weight ratio of more than 4 to 1.

It involves the design of a variety of static and moving parts: compressors, combustors, turbines, control components, gear and lube systems.

It requires men with knowledge of high speed machine design, and experience in any of the following fields:

- stress analysis
- experimental analysis of mechanics
- solid mechanics
- vibrations analysis
- mechanical analysis

And at this young, decentralized department an able man quickly advances to a position of responsibility, aided in every way by outstanding company benefits. And the cultural and recreational advantages of southern New England are within easy reach.

Write in complete confidence to:

BOX 779

Aeronautical Engineering Review

ENGINEERING TIMETABLE

Arthur Harrison, center, leads an engineering conference with four engineering heads: Lloyd W. Garrand, Van Valkenburgh, E. P. Pillsbury, Joseph Starr

MEET THE BOSS

Meet Arthur Harrison, Director of Engineering, and four outstanding chief engineers at Fairchild Guided Missiles Division.

Superintending the activities of a competent, dynamic engineering staff, Mr. Harrison directs research and development of FGMD's wide range of projects—inertial navigation, passive guidance and radar, entire missile systems, and many other related programs.

In this framework there are exciting opportunities for engineers. A place for you? Inspect the listing on the right, and if you see your qualifications, arrange an interview: you'll like what you see when you investigate the people and the working climate at Fairchild Guided Missiles Division.

Send that resume, in confidence of course, to R. B. Gulliver.

Senior Electronics Engineers:
Missile systems

Senior Electronics Engineers:
Servo and Analog Computer experience

Project Engineers:
Electronics or Electromechanical background

Senior Aerodynamicists:
Supersonic Aerodynamics, includes performance, stability and control analysis

...WHERE THE FUTURE IS MEASURED IN LIGHT-YEARS!

FAIRCHILD

GUIDED MISSILES DIVISION • WYANDANCH, LONG ISLAND, N. Y.

A Division of Fairchild Engine and Airplane Corporation

draulic Measurements. Examples. Symbols. Conversion Factors. Bibliography. Index.

FUELS & LUBRICANTS

Significance of ASTM Tests for Petroleum Products. Prepared by ASTM Committee D-2 on Petroleum Products and Lubricants, 1955. 3rd Ed. (Special Technical Publication No. 7-B.) Philadelphia, ASTM, 1956. 115 pp. $2.50.

HANDBOOKS

ASME Handbook: Engineering Tables. Edited by Jesse Huckert. New York, McGraw-Hill Book Co., Inc., 1956. 706 pp., diagrs., tables. $12.

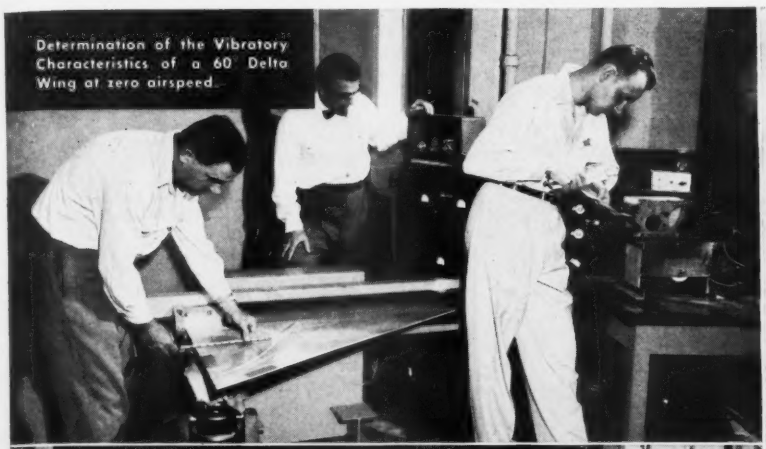
The *ASME Handbook* is the result of a survey taken in 1941 by the Metals Engineering Division of the American Association of Mechanical Engineers which revealed the need for a ready reference to the properties and characteristics of metals. The complete set will consist of four volumes. The three companion volumes are: *Metals Properties, Metals Engineering—Design,* and *Metals Engineering—Processes* (to be published). The volume being reviewed comprises 15 sections dealing with *Engineering Tables* which will supplement the designer's knowledge of standards for shape, dimension, gears, and the like. The aim is to supply a collection of tables generally recognized as standards, most often wanted by engineers and technicians, but not ordinarily found in handbooks. A table of involute functions is included; tables of squares and cubes and trigonometric functions, being easily accessible elsewhere, are not. Methods for finding the loads on ball bearings are included; the loads that ball bearings can safely carry are not. Data on bars and tubes suitable for reworking into gears, levers, shafts, or screws are included; the sizes of rolled sections as used in structures are not. Tables applicable to the design of specific parts are grouped together. To facilitate their use in design calculations, they frequently are cross-referenced. In general, a single source is given for a table—a primary one, such as the American Standards Association. Besides the national bodies, more than 50 companies have contributed engineering data and company standards. The editor is Professor of Mechanical Engineering, Ohio State University.

Contents: (1) Bar Stock and Shafting—Conversion Factors—Formulas for Stress and Strain—Properties of Sections and Cylinders. (2) Bearings—Bearing Load Analysis. (3) Spur Gears. (4) Helical and Herringbone Gears. (5) Bevel Gears. (6) Worm Gears. (7) Cylindrical Fits—Standard Tapers. (8) Keys and Keyseating. (9) Bolts—Counterbores—Screw Threads—Slots—Broached, Drilled, Reamed, and Tapped Holes. (10) Serrations and Splines, Edward Fitzgerald. (11) Nuts—Pins—Snaprings—Washers—Wrench Openings. (12) Springs, Arthur M. Wahl. (13) Aircraft and Mechanical Tubing—Pressure Tubes—Pipe—Pipe Threads and Fittings. (14) Electric Motors—Graphical Symbols—Welding. (15) Gaskets—Hydraulic Standards and Symbols—O-Rings—Packings—Seals. Bibliography.

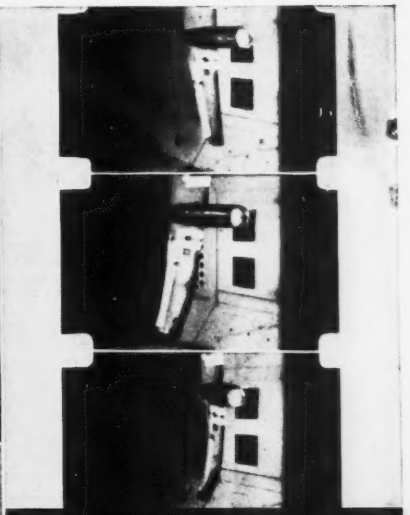
INSTRUMENTS

Applied Electrical Measurements. Isaac F. Kinnard. New York, John Wiley & Sons, Inc., 1956. 600 pp., diagrs. $15.

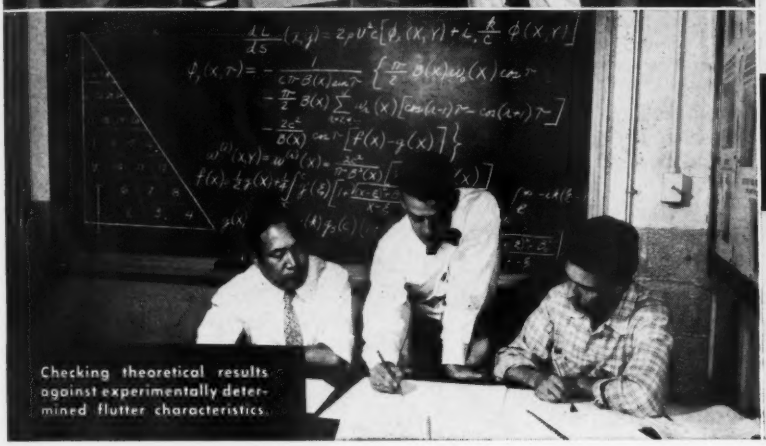
One of a series written by General Electric authors. I. F. Kinnard is Manager—Engineering, Instrument Department, General Electric Company, West Lynn, Mass. His book is a reference volume covering broadly the basic principles of commonly employed electrical measurement devices and their application to the measurement of electrical and nonelectrical quantities. It is intended for the scientist, engineer, technician, and student. Sufficient theory is given so that the principles involved can be usefully applied. Subject matter is treated within the framework of electricity, heat, statics and kinetics, liquids and gases, and time. Material is divided be-



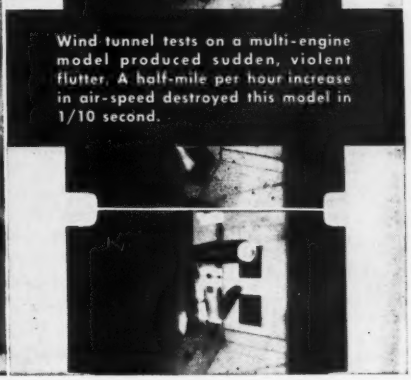
Determination of the Vibratory Characteristics of a 60° Delta Wing at zero airspeed.



Wind tunnel tests on a multi-engine model produced sudden, violent flutter. A half-mile per hour increase in air-speed destroyed this model in 1/10 second.



Checking theoretical results against experimentally determined flutter characteristics.



AEROELASTICITY

AT CORNELL AERONAUTICAL LABORATORY

Our aeroelastic program is currently concerned with the transonic flutter of low aspect ratio wings, stall flutter of supersonic propellers operating at high angles of attack, and the dynamics of helicopter rotor blades. This program is a continuation of more than ten years of creative research effort in the field of aeroelasticity. New facilities will permit the extension of experimentation into the high temperature, high supersonic field.

The aeroelastic program is one of the many technical research programs currently in progress at C.A.L. We are now working on 160 different projects dealing with almost every area of research related to the challenging problems of modern flight. Electronics, materials, atmospheric physics, weapon systems, and applied mathematics are among the many stimulating areas of research available at C.A.L. for the professional man with an inquiring mind.

CORNELL AERONAUTICAL LABORATORY, INC.
OF CORNELL UNIVERSITY

The story behind Cornell Aeronautical Laboratory and its contributions to aeronautical progress is vividly told in a 68-page report, "A Decade of Research." Whether you are interested in C.A.L. as a place to work or as a place to watch, you will find "A Decade of Research" both useful and pertinent. Mail in the coupon now for your free copy.

W. A. DIEFENBACH
CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo 21, New York

Please send me "A Decade of Research."

Name _____

Street _____

City _____ Zone _____ State _____

☐ Please send employment information.

DEPARTMENT OF TECHNOLOGY
BUFFALO AND ERIE COUNTY PUBLIC LIBRARY

ANALYTICAL ENGINEERS

At Hawthorne, in Southern California, Northrop Aircraft has a continuing need for experienced engineers seeking new opportunities. There are attractive positions open in the following fields: Aerodynamics, Dynamics, Thermodynamics, Stress, Loads, Performance Analysis.

In Northrop's superbly equipped multi-million-dollar engineering and science center, now nearing completion, you will be given constantly fresh and challenging assignments. Present programs include Northrop's new supersonic trainer airplane, the Snark SM-62 intercontinental guided missile, plus advanced aircraft and missile projects yet to be revealed.

You'll be associated with a high-calibre engineering team that has established an outstanding record in aeronautical design and development. Your initiative and ideas will be recognized, encouraged and rewarded, for at Northrop Aircraft the progress of personnel is as important as the progress of projects.

Besides attractive remuneration, you will enjoy other benefits unexcelled in the entire industry—retirement plans, health and life insurance, college educational reimbursement plan, regular vacations plus extra year-end vacations with pay. Easily-reached mountain, desert and beach resorts in sunny Southern California offer year 'round attractions for you and your family.

You will find the career opportunity you are seeking at Northrop, pioneer in the design and production of all weather and pilotless aircraft. If you qualify for one of these attractive positions, contact the Manager of Engineering Industrial Relations, Northrop Aircraft, Inc., ORegon 8-9111, Extension 1893, or write to: 1015 East Broadway, Department 4600-Q, Hawthorne, California.

NORTHROP

NORTHROP AIRCRAFT, INC., HAWTHORNE, CALIFORNIA

Producers of Scorpion F-89 Interceptors and Snark SM-62 Intercontinental Missiles

5-A-89

tween two sections covering both the measurements of electrical quantities and nonelectrical quantities. Some of the chapters cover the historical background, theory, and analysis of measurement and review the state of the application art in selected fields of measurement. Extensive bibliographies accompany each chapter. The rationalized mks system of units has been used throughout the text, and definitions of terms and mathematical and graphical symbols are those recommended by the American Standards Association. The book also utilizes a systematic and logical method of analysis developed by the author with some of his associates and called "Functional Analysis of Measurements." Presented to the American Institute of Electrical Engineers as a paper, the terms and definitions of "Functional Analysis of Measurements" are to be incorporated in the next edition of the *American Standard Definitions of Electrical Terms*.

MATERIALS

Elevated-Temperature Properties of Coppers and Copper-Base Alloys. Clair Upthegrove and Henry L. Burghoff. Data Compiled by and Issued Under the Auspices of the Data and Publications Panel of the ASTM-ASME Joint Committee on Effect of Temperaure on the Properties of Metals. (ASTM Special Technical Publication No. 181.) Philadelphia, ASTM, 1956. 244 pp., diagrs., tables. $5.50.

A text that is completely graphical in form. Graphical data include modulus of elasticity, tensile strength, yield strength (0.5 per cent extension on 0.2 per cent offset), reduction of area, elongation, stress for creep rates of 0.000001, 0.00001, and 0.0001 per cent per hour, and stresses for rupture in 100, 1,000, 10,000, and 100,000 hours. Data for the coppers are limited to the wrought materials, while the data for the alloys apply to cast and wrought materials.

MATHEMATICS

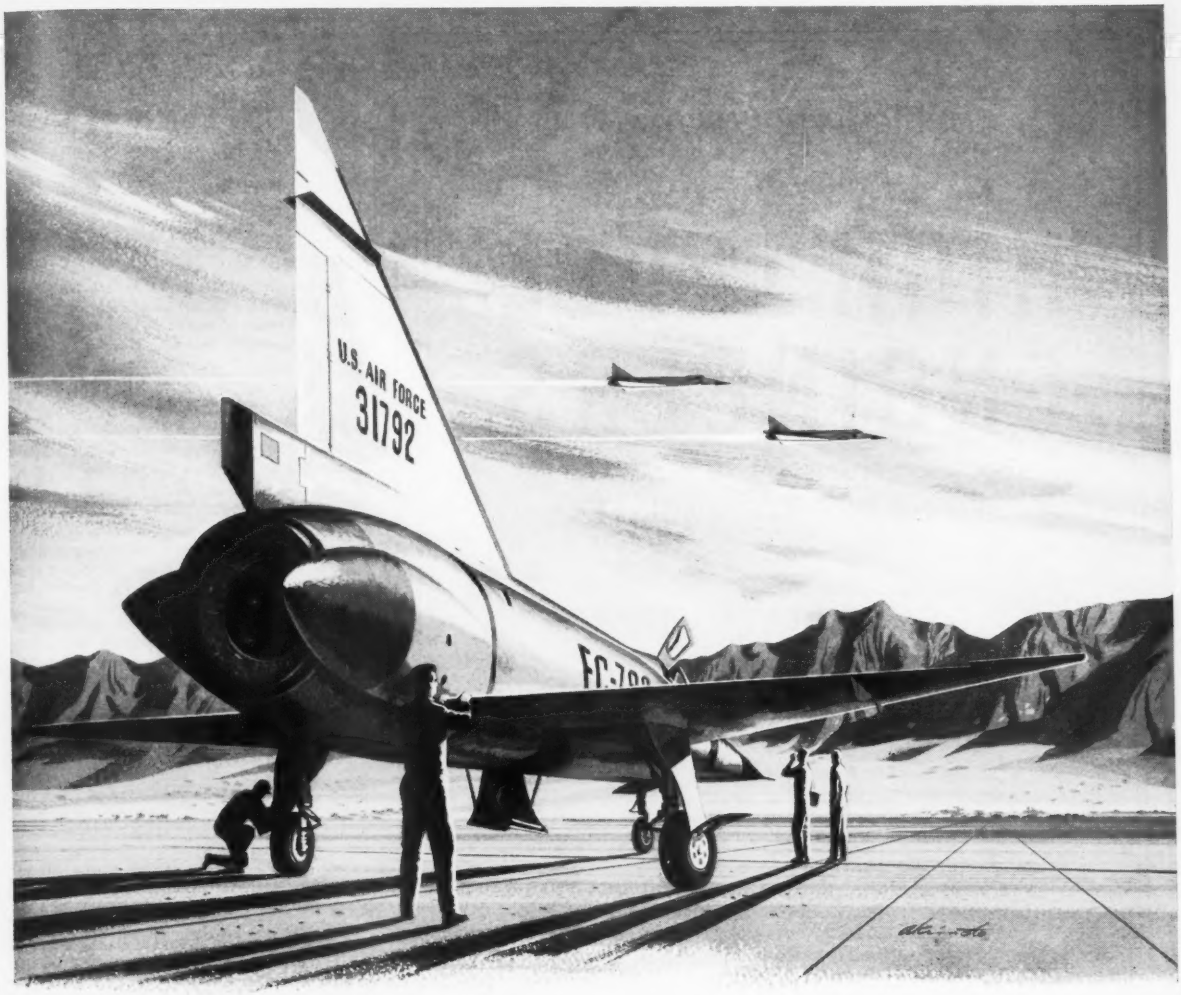
Ordinary Non-Linear Differential Equations in Engineering and Physical Sciences. N. W. McLachlan. 2nd Ed. Oxford, Clarendon Press, 1956. 271 pp., diagrs. $6.30.

Expanded by 130 pages over the 1950 edition, the text gives a practical introduction to nonlinear differential equations for engineers, physicists, and students. The additions include: (1) derivation of nonlinear differential equations satisfied by Jacobian elliptic functions; (2) a new version of the stability problems of the synchronous motor; (3) a chapter on singular points of differential equations, stability criteria, their derivation and application; (4) four theorems on the types of solution of certain nonlinear differential equations; (5) a chapter on fluid flow in two dimensions; and (6) 52 problems with answers. The author is at present Visiting Professor of Electrical Engineering, Pennsylvania State University.

NUCLEAR ENERGY

Nuclear Fuels. Edited by David H. Gurinsky and G. J. Dienes. (The Geneva Series on the Peaceful Uses of Atomic Energy, James G. Beckerley, Editor.) Princeton, N.J., D. Van Nostrand Co., Inc., 1956. 364 pp., illus., diagrs., tables. $7.50.

The International Conference on the Peaceful Uses of Atomic Energy, held in August, 1955, made available a tremendous amount of declassified technical information. The most urgently useful of this material has been distilled into a six-volume set. Each volume covers a specific subject and is edited by an authority in the field. Both the editors of the present volume are associated with Brookhaven National Laboratory, Dr. Gurinsky as Head, Metallurgy Division, and Dr. Dienes as Senior Physicist. In presenting the current status of the field of nuclear fuels, they have divided the material into three sections—the metallurgy of uranium and thorium, radiation effects, and solid and fluid fuels. The purpose has been to introduce the



IDEAL ENGINEERING "CLIMATE"

The many advanced aircraft and missile programs at Convair San Diego today include: *The F-102A Supersonic Interceptor, The Atlas Intercontinental Ballistic Missile, The Metropolitan 440 Airliner, the new Convair 880 Jet-Liner, and a far-reaching study of Nuclear Aircraft.*

Within these vital, highly-diversified Convair projects in beautiful San Diego, California, engineers find the perfect "climate" for a challenging and rewarding engineering career. You will find Convair salaries, computor and test facilities, engineering policies, educational opportunities and personal working advantages the most desirable in the industry.

What's more, you and your family will almost certainly enjoy a new, exciting, happier way of life here . . . where the weather year 'round is unsurpassed.

For a significant engineering career in the engineering "climate" *you* seek, we invite you to forward a full resume today. Write H. T. Brooks, Engineering Personnel, Dept. 1523.

Generous travel and moving allowances to engineers.

CONVAIR

C-V GD

A DIVISION OF GENERAL DYNAMICS CORPORATION

3302 PACIFIC HIGHWAY SAN DIEGO, CALIFORNIA

Immediate Openings for

HIGH LEVEL ENGINEERS

SENIOR PROJECT ENGINEER

For Gas Turbine Development

CHIEF EXPERIMENTAL ENGINEER

For Gas Turbine Development

PROJECT ENGINEERS

For Pneumatic Ducting,
Gas Turbine Production

Solar's present expansion program has resulted in several desirable openings for high level engineers to work on advanced development and production projects. Here is an unusual opportunity. Advance your career at Solar...while enjoying the unique delights of San Diego's year-round, moderate, sunny climate. Take advantage of this opportunity created by the expansion of Solar's Engineering Division. Please send a resumé of your qualifications and education to Louis Klein, Dept. E-115, Solar Aircraft Company, 2200 Pacific Highway, San Diego 12, Calif.

SOLAR AIRCRAFT COMPANY — SAN DIEGO, DES MOINES

Designers, Developers and Manufacturers • Gas Turbines • Aircraft and Missile Components • Bellows • Controls • Coatings • Metal Alloy Products

Solar also has permanent openings for:

CONTROLS ENGINEERS • DESIGN ENGINEERS

DESIGNERS • DRAFTSMEN • CHECKERS

ENGINEERING WRITERS

reader to the basic information necessary for designing a fuel system, to point out problems specific to reactor systems, and to show how engineering requirements and the fundamentals produce specific fuel systems. The editors consider the work as a detailed introduction to the field with subject and name indexes, references, sources, and bibliographies as background for further study.

The Biological Effects of Atomic Radiation; Summary Reports from a Study by the National Academy of Sciences. Washington, National Academy of Sciences, National Research Council, 1956. 108 pp.

The Biological Effects of Atomic Radiation; A Report to the Public from a Study by the National Academy of Sciences. Washington, National Academy of Sciences, National Research Council, 1956. 40 pp.

PHYSICS

The Mathematics of Diffusion. J. Crank. Oxford, Clarendon Press; New York, Oxford University Press, 1956. 347 pp., diagrs. $8.00.

A treatise on the mathematical work which has been done in diffusion within the last 10 years. The mathematical theory of diffusion is founded on that of heat conduction, and correspondingly the early part of the book has developed from *Conduction of Heat in Solids* by Carslaw and Jaeger. Some of their solutions are applied to diffusion problems for which the diffusion coefficient is constant. Early chapters review work of a considerable period that is still applicable, and solutions that will be of most interest for problems with constant diffusion coefficients are presented graphically and evaluated numerically. Later chapters deal mostly with work of the past 10 years and with problems for which the coefficients are not constant and for which graphical and numerical methods must be used. Separate chapters discuss diffusion equations; methods of solution when the diffusion coefficient is constant; infinite and semi-infinite media; diffusion in a plane sheet, in a cylinder, in a sphere, with a moving boundary; simultaneous diffusion and chemical reaction; methods of solution for variable diffusion coefficients; finite-difference methods; definition and measurement of diffusion coefficients; calculated results for variable diffusion coefficients; and simultaneous diffusion of heat and moisture. The author is a member of the Research Laboratory, Courtaulds, Ltd.

POWER PLANTS

Rocket Propulsion Elements; An Introduction to the Engineering of Rockets. George P. Sutton. 2nd Ed. New York, John Wiley & Sons, Inc., 1956. 483 pp., illus., diagrs., tables. $10.25.

A broad treatment of the basic elements and the technical problems of the physical mechanisms, applications, and designs of rocket-propulsion systems. The text, consisting of 200 pages more than the 1949 edition, is now organized into three broad categories: (1) liquid propellant rockets, their working fluids, and their design; (2) solid propellant rocket fundamentals, working substances, and solid propellant rocket design; and (3) general principles of thermodynamics, chemistry, heat transfer, flight theory, historical background, and testing methods. The author is Instructor, University of California, and Engineering Section Chief, Rocketdyne Division, North American Aviation, Inc.

Aircraft Propulsion Data Book, 1956. Cincinnati, Aircraft Gas Turbine Division, General Electric Co., 1955. 192 pp., diagrs., maps, tables.

A pocket-size, quick-reference volume with information almost entirely in tabular form. The sections are divided as follows: (1) Properties of Air. (2) Aerodynamics. (3) Propulsion Systems. (4) Materials, Fuels, and Oils. (5) General Technical Data. (6) Military Information. (7) General Electric Company Information. (8) Miscellaneous Information.

Engineers

(in a series of independent surveys)

ABOUT JOB OPPORTUNITIES

Here are Republic Aviation's Answers

..... At REPUBLIC AVIATION expansion has added 43 new supervisory engineering positions in the last 3 years to 156 already existing. 77% were filled by engineers on the staff from 1 to 20 years; 23% from outside the company. 54 additional technical specialist openings created in last 12 months with 26 filled from within.

100% of Republic engineers have received pay increases since January, 1955 and 40% have won increased professional status.

..... At REPUBLIC, top of the industry scale is in force at all levels, but individual contributions bring added financial and professional recognition.

..... Pioneering new concepts in aircraft design and missile science is the business of Republic Aviation. With such planes as the incredible new F-105 Thunderchief (5th in the series of famous Thundercraft) to its credit, the company is now attacking the fantastic problems involved in hypersonic flight. Advanced problems are being studied by the newly organized Scientific Research Staff.

The Missiles Division is engaged in upper atmosphere research and kindred areas (military proposals, contractual projects and company-sponsored programs).

..... We may be prejudiced but at REPUBLIC we think our location — LONG ISLAND — is very hard to beat. This is the famous playground of the East Coast, where modern suburban communities are within easy reach of fabulous beaches... where a man can keep his own boat, play golf, tennis — even polo — yet be less than an hour away from downtown New York with its cultural, educational and entertainment facilities.

..... At REPUBLIC, benefits include our famous 2-PART RETIREMENT INCOME PLAN that's a model for the industry. Also EDUCATIONAL AID, covering 2/3 the cost of advanced study; BROAD INSURANCE COVERAGE — Life, Accident and Health plus Hospital-Surgical Benefits for the whole family.

ALL-EXPENSE PAID RELOCATION PLAN for qualified engineers living outside the New York City-Long Island area

Please send complete resume, including details of technical background, to:

AIRCRAFT
Mr. D. G. Reid
Engineering Personnel Manager
Farmingdale, L. I., N. Y.

MISSILES
Mr. R. R. Reissig
Administrative Engineer
233 Jericho Tpke., Mineola, L. I., N. Y.

REPUBLIC AVIATION

SAFETY

Survey of Research Projects in the Field of Aviation Safety. Fifth Annual Supplement, July, 1956. New York, The Daniel & Florence Guggenheim Aviation Center at Cornell University, 1956. 19 pp.

The sixth in a series of annual surveys listing information on nonclassified research conducted in various fields affecting aviation safety. This supplement is not a bibliography of reports but a listing of new research projects established during 1955. The 110 projects are divided into five sections: Accident Prevention and Protection, Air Transportation, Aviation Medicine, Operating Problems, and Miscellaneous. Each project is coded and cataloged under several general subjects. The entries give the title, description of the work, the sponsor and location, and the code number for reference at the Aviation Safety Center. Included as part of the report is a descriptive outline and guide recommending revision and future research in the following fields: air traffic control, mid-air collisions, human engineering, occupant protection, crash fire protection, steep gradient aircraft, private flying hazards, jet operating problems, metal fatigue, and airport modernization.

STRUCTURES

Minimum Weight Analysis of Compression Structures. George Gerard. New York, New York University Press; Distributed by Interscience Publishers, Inc., 1956. 194 pp., illus., diagrs., tables. $6.00.

In order to evaluate from the viewpoint of structural efficiency the available forms of aircraft construction and those that may be devised by designers and research men, it is necessary to establish analytic methods for obtaining minimum weight designs of the various types of construction. Since the major structural dimensions are generally based on certain of the aerodynamic and propulsion requirements, the analysis must be conducted for specified loading and geometric parameters. Chapter 1 discusses the principles of minimum weight analysis and design of individual compression elements subject to buckling. It also includes a survey of some of the published literature on optimum design of elements in which the dimensions involving the supporting structures are arbitrarily fixed. Chapters 3–7 are devoted to an analysis of the minimum weight configuration of the compression cover and supporting structure under bending loads of the following structural arrangements: stringer panel-rib construction, transversely stiffened plates, post construction, multicell construction, post-stringer construction, sandwich-plate construction, sandwich-box construction, unstiffened cylindrical shells, stringer panel-frame shells, and sandwich shells. Chapter 8 compares the various types of construction for efficiency in bending. This has been done for aluminum alloy 75 S-T. From this procedure, the ranges of efficient structural application of each form of construction can be established. Since the conclusions obtained from the minimum weight analyses are based on certain idealizations and assumptions, Chapter 9 is devoted to a discussion of considerations that tend to favor one form of construction over another. To establish ranges of efficient structural application of the various types of construction for materials other than aluminum alloy 75 S-T, the physical properties influencing the choice of materials for minimum weight applications are considered in Chapter 10. Finally, Chapter 11 analyzes the ideal stress for minimum weight. The Appendix contains a historical Review of Literature on Minimum Weight Analysis with a Chronological Bibliography. Preceding the text will be found an interpretative List of Symbols used throughout the book. The author is Assistant Director, Research Division, College of Engineering, New York University.

Die Stabilität der versteiften Platten und Schalen (The Stability of Reinforced Plates and Shells). J. R. M. Radok. Groningen, Netherlands, P. Noordhoff N.V., 1955. 47 pp., figs. $0.75.

This treatise is concerned with the determination of the critical loads at which the instability of thin walls occurs. It does not go further into the investigation of this unstable state. Two structural elements are considered—flat rectangular plates and full circular cylindrical shells whose free edges are supported. In the case of plates, the reinforcements are arranged parallel to the edges whereas the cylindrical shells possess either longitudinal or ring-shaped reinforcements. In both cases, the reinforcements are disposed parallel to the wall on both sides so that the center plane of the wall is a symmetrical surface.

THERMODYNAMICS

Abstracts of Papers Presented at the Sixth Symposium (International) on Combustion; Held at Yale University, New Haven, Conn., August 19–24, 1956. Pittsburgh, The Combustion Institute, 1956. 208 pp. $3.00.

Here are abstracts of 126 papers, ten of which were not presented at the meeting but are to be published. The abstracts are from 400 to 1,200 words in length and contain any necessary references, equations, formulas, or diagrams. The papers are devoted to the following aspects of the subject: Structure and Propagation of Laminar Flames, Flame Stabilization in Fast Streams, Experimental and Analytical Techniques in Combustion, Applications of Combustion, Instability in Combustion Chambers, Combustion of Solid Fuels, Evaporation and Combustion of Droplets and Sprays, Combustion of Explosives and Solid Propellants, and Structure and Propagation of Turbulent Flames. The index not only lists alphabetically the 209 authors but serves as a directory by giving the professional affiliation and location of each individual.

WIND TUNNELS

Papers Presented at the Seventh Meeting of the Wind Tunnel and Model Testing Panels, AGARD, NATO, Ottawa, Canada, June, 1955. (AG 19/P9.) Paris, AGARD; Washington, Distributed in U.S. by NACA, 1956. 331 pp., illus., diagrs., tables.

Contents: (1) The Representation of Engine Airflow in Wind Tunnel Model Testing, J. Seddon and L. F. Nicholson. (2) The Influence of Turbojet Airflow on the Aerodynamic Design of Airplanes, Harold Luskin and Harold Klein. (3) The Simulation of the Effects of Internal Flow in Wind Tunnel Model Tests of Turbojet Powered Aircraft, Albert J. Evans. (4) Boundary Layers on Swept Wing; Their Effects and Their Measurement, D. Küchemann. (5) The Use of Pitot Tubes in the Measurement of Laminar Boundary Layers in Supersonic Flow, R. J. Monaghan. (6) Methode de Calcul de la Couche Limite Tridimensionnelle; Application à un Corps Fusele Incline sur le Vent, E. A. Eichelbrenner and A. Oudart. (7) A Brief Review of Three-Dimensional Boundary-Layer Flows, W. R. Sears. (8) The Simulation and Measurement of Aerodynamic Heating at Supersonic and Hypersonic Mach Numbers, Jackson R. Stalder and Alvin Seiff. (9) The Status of Heat Transfer and Friction Investigations at Supersonic Speeds, H. H. Kurzweg. (10) The N.R.C. Icing Wind Tunnels and Some of Their Problems, C. K. Rush. (11) Wind Tunnel Simulation of Atmospheric Icing Conditions, C. K. Rush and R. L. Wardlaw. (12) The Fluid Flow Associated with the Impact of Liquid Drops with Solid Surfaces, P. Savic and G. T. Boult. (13) The Icing Problem—Current Status of N.A.C.A. Techniques and Research, Uwe H. von Glahn.

Available

Reprints of Nineteenth Wright Brothers Lecture

"Some Structural and Aeroelastic Considerations of High-Speed Flight"

By R. L. Bisplinghoff, Professor of Aeronautical Engineering, Massachusetts Institute of Technology

Member Price $1.00 **Nonmember Price $1.50**

Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

Engineering Instructors—Increased enrollment requires teaching staff expansion creating several openings soon for industry-experienced men, with or without teaching experience, to serve as instructors in the various phases of practical aeronautical engineering. Retired or semiretired persons desiring California residence and light workload can be employed for as little as 2 or 3 hours per day. American citizenship not required. Leaflet of full particulars about our kind of teaching, also the school catalog, will be furnished on request. Send replies to C. T. Reid, Director of Engineering, Northrop Aeronautical Institute, 1155 W. Arbor Vitae St., Inglewood 1, Calif.

Aeronautical Engineering Group Superintendent—The Bureau of Aeronautics, Navy Department, has an opening for an Aeronautical Engineering Group Superintendent at the Naval Air Station, Alameda, Calif. The salary for this key position is at the GS-14 level, $10,320 per annum. This superintendent is the top civilian reporting to the Naval Officer in charge of the Aeronautical Engineering Group. A minimum of 10 years' education and experience is required—a Bachelor's degree in aeronautical or a related branch of engineering, plus at least 6 years of professional engineering experience, including 3 years of supervisory experience. Standard Form 57, Application for Federal Employment, which may be obtained at any first- or second-class Post Office, should be sent to the Bureau of Aeronautics, Personnel Division (PE-252), Main Navy Building, Washington 25, D.C.

Aeronautical Engineers—The following vacancies exist for aeronautical engineers at the U.S. Naval Training Device Center, Sands Point, Port Washington, L.I. **Aeronautical Engineer**—$4,480 per annum (Requirement: BAE degree); **Aeronautical Engineer**—$5,335 per annum (Requirement: BAE degree plus 6 months' professional experience in aeronautical engineering); **Aeronautical Engineer**—$6,115 per annum (Requirement: Degree in engineering plus 18 months' professional experience, of which 1 year must be in aeronautical engineering); **Aeronautical Engineer**—$7,035 per annum (Requirement: Degree in engineering plus 2½ years' professional experience, of which 1 year must be in aeronautical engineering). Inquiries regarding these vacancies should be addressed to Industrial Relations Officer, U.S. Naval Training Device Center, Sands Point, Port Washington, L.I., N.Y. Telephone inquiries may be made to Port Washington 7-3800, Ext. 207 or 208.

The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

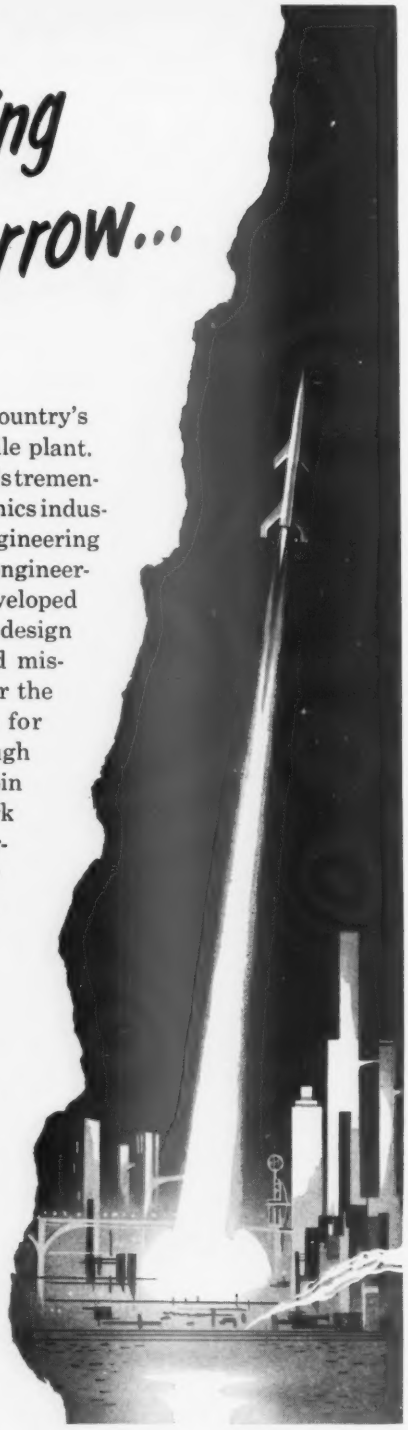
Aeronautical Engineers—The Navy Department, Bureau of Aeronautics, has a number of positions available in the following fields of aeronautical engineering including research and development on aircraft and guided missiles, structural loads, vibration and flutter, aerodynamics, power plants, cruise control, performance, ships installation of aircraft and missiles, and related mechanical, electrical, and electronic components. Salaries for most positions are at the GS-11, $7,035 per annum, and GS-12, $7,570 per annum, levels, although some positions may be available at the GS-13 level, $8,990 per annum. Positions require 2½ to 5 years of experience. Applications made on Standard Form 57 (available at most Post Offices and Government offices) should be sent to the Bureau of Aeronautics, Personnel Division (PE-202), Main Navy Building, Washington 25, D.C.

Supervisory Materials Engineer—$7,035 per annum. Duties (Condensed): Incumbent is head of the Materials Laboratory Branch, Materials and Process Division, Aeronautical Engineering Group, Overhaul and Repair Department. He assists the Materials Engineer (Division Superintendent) in accomplishing work of an engineering and administrative nature through counsel in planning and organization and by directing the personnel in the branch by immediate supervision. He is in charge of all laboratory work which embraces metallurgical investigations, analytical chemistry, and physical testing; acts as a project engineer and is directly in charge of the X-ray section. Qualifications (Condensed): A full 4-year course in an accredited college or university approved by the Engineer's Council for professional development leading to a Bachelor's degree, plus 2½ years of progressive professional experience with at least 1 year of this experience in materials engineering or 6½ years of progressive technical engineering experience with at least 1 year of this experience in materials engineering. **Supervisory Production Metallurgist (Physical)**—$7,035 per annum. Duties (Condensed): Serves as head of the Metallurgical Branch, Materials and Process Division, Aeronautical Engineering Group, Overhaul and Repair Department. Assists the Division head in accomplishing engineering and administrative work through counsel in planning and organization and by directing the personnel in the Metallurgical Branch. Responsible for preparation of all local process specifications, local engineering specifications, engineering instructions, reports, and other technical directives pertaining to metallurgical processes, including X-ray and nondestructive inspection. Directs all work required in the developing and establishing of new processes and makes periodic checks of processing methods used in various production shops to

INDEX TO ADVERTISERS seeking Engineering Personnel

COMPANY AND LOCATION	PAGE
AC Electronics Division, Milwaukee	192
Aerojet-General Corp., Azusa, Calif	110
AiResearch Mfg. Divisions, Los Angeles; & Phoenix, Ariz	120
Allied Research Associates, Inc., Boston	193
Armour Research Foundation, Chicago	183
Avco Defense & Industrial Products, Stratford, Conn	134
Beechcraft, Wichita, Kan	192
Bell Aircraft Corp., Buffalo	197
Boeing Airplane Co., Seattle; Wichita, Kan.; & Melbourne, Fla.	191
The Budd Co., Philadelphia	193
Caltech Jet Propulsion Laboratory, Pasadena, Calif	30
Cessna Aircraft Co., Wichita, Kan	183
Convair Division	
Pomona, Calif	190
San Diego, Calif	181
Cornell Aeronautical Laboratory, Buffalo	179
Douglas Aircraft Co., Inc., Santa Monica, Calif	202
Fairchild Engine & Airplane Corp.	
Engine Division, Deer Park, N.Y.	162
Guided Missiles Division, Wyandanch, N.Y.	178
General Electric Co., Cincinnati; & Idaho Falls, Idaho	192, 197
Philadelphia	183
Hughes Aircraft Co., Culver City, Calif	14
Johns Hopkins University, Silver Spring, Md	194
Joy Mfg. Co., New Philadelphia, Ohio	177
Kaman Aircraft Corp., Bloomfield, Conn	167
Lockheed Aircraft Corp., Van Nuys & Sunnyvale, Calif	187
The Glenn L. Martin Co., Denver	176
McDonnell Aircraft Corp., St. Louis	155
Minneapolis-Honeywell Regulator Co., Minneapolis	192
North American Aviation, Inc., Los Angeles	174, 193
Columbus Division	195
Northrop Aircraft, Inc., Hawthorne, Calif	180
Pennsylvania State University, University Park, Pa	183
Ramo-Wooldridge Corp., Los Angeles	188
Republic Aviation Corp., Farmingdale & Mineola, N.Y.	185
Solar Aircraft Co., San Diego, Calif	182
Southern Calif. Cooperative Wind Tunnel, Pasadena, Calif	199
Temco Aircraft Corp., Dallas, Tex	173

Engineering for Tomorrow...



...at Convair-Pomona the country's first exclusive guided missile plant. Here in the heart of America's tremendously fast growing Electronics industry, we at Convair are engineering for tomorrow today! The engineering miracles now being developed for America's defense in the design and manufacture of guided missiles is the groundwork for the fantastic future in store for America tomorrow through electronic engineering. Join the Convair team now, work in America's finest engineering facility. Completely modern... Completely air conditioned.

Excellent opportunities now available in:

ELECTRONICS
AERODYNAMICS
DYNAMICS
THERMODYNAMICS
OPERATIONS RESEARCH
HYDRAULICS
MECHANICAL DESIGN
LABORATORY TEST ENGINEERING

Generous travel allowance to Engineers who are accepted. Write now enclosing a complete resume to:

Employment Department 3-N

CONVAIR
A DIVISION OF
GENERAL DYNAMICS
CORPORATION
POMONA
CALIFORNIA

determine the need for technical improvements. Qualifications (Condensed): A full 4-year course in an accredited college or university, including 20 semester hours in metallurgical subjects, plus 2½ years of progressive practical experience or 6½ years of progressive technical experience. In each case, at least 2 years of this experience must have been in metallurgy. Application forms and further information may be secured from the Industrial Relations Officer, Industrial Relations Department, U.S. Naval Air Station, Quonset Point, R.I.

Engineering Assistant—In the field of theoretical and experimental stress analysis. Applicant should be a recent college graduate with a B.S. or M.S. in mechanical engineering. Mail qualifications to Brewer Engineering Laboratories, P.O. Box 157, Marion, Mass.

Air-Frame, Flight-Test, and Power-Plant Engineers—GS-5 to GS-12 levels; salaries ranging from $4,480 to $8,645 per annum. Positions are concerned with the development and administration of airworthiness standards; the design, evaluation, and testing of aircraft; and aircraft engines, propellers, equipment, electrical and electronic systems, and instruments for compliance with airworthiness standards. Grade level will be determined by the amount and quality of experience. Minimum qualifications are as follows: for GS-5—bachelor's degree; for GS-7—degree plus 6 months' professional experience; for GS-9—degree plus 1½ years' professional experience; for GS-11—degree plus 2½ years' professional experience; and for GS-12—degree plus 3½ years' professional experience. Applicants should submit Standard Form 57, Application for Federal Employment, to the nearest CAA Personnel Office at the following locations: 16th & Constitution Avenue, N.W., Washington 25, D.C.; International Airport, Jamaica, L.I., N.Y.; P.O. Box 1689, Ft. Worth 1, Tex.; 911 Walnut Street, Kansas City 6, Mo.; P.O. Box 45007, Airport Station, Los Angeles.

Engineers—The Turbomotor Division of Curtiss-Wright Corporation is a new and rapidly expanding organization which will concentrate on the design and development of aircraft and missile propulsion systems in the low to medium power categories. Immediate openings exist for engineers qualified in the fields of compressor design, combustion, turbine design, mission analysis, and structural analysis. Starting salaries to $15,000, depending upon qualifications. A particularly attractive key position currently available is that of Performance Analysis Supervisor. Also available is a supervisory position in the field of Laboratory Operations. Send résumé to Nicholas Vrabel, Turbomotor Division, Curtiss-Wright Corporation, Princeton, N.J.

771. Engineer—Patents—Aircraft Service Organization has openings in New York City for engineering graduates with suitable educational background or experience in the aeronautical arts; aerodynamics, power plants, or plastics are preferred fields. Salary commensurate with education and any previous experience. Duties involve patent research. Exceptional opportunity, especially for those desirous of entering the patent field with chance to learn various phases of patent work including contact with U.S. Patent Office and corporate patent activities. Usual employee benefits, including pension plan and training program which includes tuition for law school or other advanced study.

770. Professor—An opening exists for a man with a Doctor's degree for teaching and part-time research in aeronautical engineering. Salary and rank open. Outstanding individual with proved ability desired. Field of specialty open: aerodynamics, structures, aeroelasticity. Location, deep Southeast. Please submit complete data on qualifications, together with small photograph.

Available

777. Aeromechanical Engineer—B.S. in M.E. Many years' experience as project leader in re-

OUTSTANDING OPPORTUNITIES *in* Aircraft NUCLEAR PROPULSION

Are Now Available at The Budd Co. in Philadelphia

Our new long range program has created challenging and responsible positions in our nuclear engineering division for men with some experience and seeking advancement in the following groups:

MECHANICAL ENGINEERS
For Structural Analysis

MECHANICAL DESIGN ENGINEERS
Thermodynamic Analysts

PROJECT ENGINEERS
Mechanical Background

Salaries Commensurate With Experience

Call or write for personal and confidential interview or mail a complete resume to:

The BUDD Company

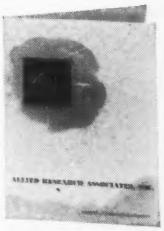
Employment Service Dept.
2450 Hunting Park Avenue
Philadelphia 32, Pa.

ENGINEERS
PHYSICISTS
CHEMISTS

a few frank words about your salary!

Your present skills may well be worth more at Allied Research Associates, Inc. Here, conditions for professional growth are ideal. This is a young New England organization of research consultants. It is not too large. It is not over-specialized. You work in small project groups where recognition comes faster, and individual contributions are vitally important. You have a better chance for a position of more responsibility, greater earning power — for here, real responsibility commands real money.

OPPORTUNITIES IN THESE EXPANDING FIELDS:
Theoretical and applied aerodynamics — Stability and control — Aeroelasticity — Thermo-elasticity Vibrations analysis—Mechanical design—Applied mechanics — Aircraft and guided missile studies Weapons effects — High temperature physics Spectroscopy—Instrumentation—Radiation transfer



Please send resume to D. J. Fink, Chief Project Engineer. Ask for free booklet containing the full story of Allied Research.

ALLIED RESEARCH ASSOCIATES, INC.
43 LEON STREET, BOSTON, MASS.

Select California engineering group explores thermodynamic cycles in advanced engines

positions now open for Cycle Analysis... Thermodynamics... and Nuclear Engineers

Propulsion experts at North American Aviation's Los Angeles Division are carrying out thermodynamic analyses of highly advanced engines. The studies include investigation of turbojets, ramjets, rockets and nuclear propulsion devices...compressors, combustors, turbines, afterburners, exhaust nozzles and thrust augmentation devices.

The Engineering Personnel Department at North American's Los Angeles Division is seeking several qualified engineers who are interested in this work. They are looking for men who have had a minimum of three years thermodynamics cycle analysis experience in jet engines or propulsion analysis. Advanced degrees are preferred, though not required.

Interested engineers are invited to contact Mr. W. H. Nance, North American Aviation, Inc., Los Angeles Division Engineering Dept. 56AER, International Airport, Los Angeles 45, California.

ENGINEERS

Aerodynamics & Propulsion

APL-An Organization Of And For Technical Men And Scientists

The Applied Physics Laboratory (APL) of the Johns Hopkins University is an organization *of* and *for* technical men and scientists. Several factors allow for more effective utilization of "mind power" at APL. They lead to tangible and intangible satisfactions for staff members that could not be gained elsewhere.

Among them are:

1. Individual staff members are given a measure of responsibility and initiative much greater than in many comparable establishments. Decision-making, on *all* levels, is placed in the hands of scientists and technical men.

2. Staff members do not restrict their efforts to limited technical problems. Instead they are asked to assess and solve problems of a systems nature, including analyses of *complete tactical problems.*

3. APL handles technical direction of the work of many associate and sub contractors, including 21 universities and leading industrial organizations. As a result, APL staff members enjoy a rewarding exchange of ideas and techniques with other leaders in R & D.

4. The combined facilities of APL, its associate and sub contractors, and Government test stations provide opportunities for members of its technical staff to develop and exploit their varied capabilities in a unique environment where teamwork and individual initiative are fused.

5. This *esprit* and freedom to look into new concepts has resulted in a number of "quantum jumps" in defense capability, including the proximity fuze, the first supersonic ramjet engine, and the Navy's Bumblebee family of missiles which includes TERRIER, TALOS and TARTAR. APL is presently attempting break-throughs on several important fronts.

APL's expansion program recently witnessed the completion of new laboratories covering 350,000 sq. ft. in Howard County, Maryland, equidistant from Washington, D. C. and Baltimore. Men of originality are invited to inquire about staff opportunities. Salaries compare favorably with those of other R & D organizations.

OPENINGS EXIST IN:

DEVELOPMENT: Stability and control analysis; ramjet engine design; preliminary design and wind-tunnel testing.

RESEARCH: Interference and heat transfer phenomena; internal aerodynamics; hypersonics, turbulence, shock wave phenomena; combustion.

For Additional information write: Professional Staff Appointments

The Johns Hopkins University Applied Physics Laboratory

8605 Georgia Avenue, Silver Spring, Md.

search, development, and product engineering in the fields of propulsion (jet engines and rockets), hydrodynamics, structures, and missile design. Cooriginator of an important new missile. Thoroughly experienced in project costs, production and quality control, handling subcontracts, liaison with defense agencies, and supervision of large groups.

776. Contract Administration or Administrative Engineering—B.S. in Aeronautical Engineering. Has almost completed Master's degree in Industrial Management; 7 years' Air Force experience as aircraft weapons system project officer—project engineering, procurement and production. Prefers New York City area. Résumé sent upon request.

775. Staff or Executive Engineer—Outstanding in ability to correlate between scientific, engineering, production, management, and supplier organizations. Can assist top executive or administer group in mechanical or related fields. Broad coverage of light to heavy mechanical activities through 21 years of integrated management, design, development, and research. Broad progressive interests, registered, advanced degree. Salary five figures plus.

772. Engineer-Writer—M.S., mature, with extensive background in aeronautical engineering, major structural analysis, and technical writing; varied experience with general engineering projects. Traveled. Desires teaching position or research with school or university, preferably New England or California. Résumé on request.

769. Analytical Engineer—B.S., M.A. (Math.), B.M.E. Ten years' experience in engineering research and development, including 8 years in aerodynamics; also 8 years' teaching experience and 3 years in sales. West Coast or New York area preferred. Nonmilitary projects preferred.

768. Product Development Engineer—Graduate M.E. with 6 years' air-frame structural design and 3 years' fastener design experience. Has supervisory responsibility for the design and development of aircraft hardware reporting directly to Vice-President. Introduction and promotion of new products to the aircraft industries at the design and purchasing levels. Company representative at Government- and industry-sponsored meetings. Several patents pending on fastening and related devices. Desires staff-level position with aircraft components or hardware manufacturer.

Attention Members!

All Members of the Institute are invited to submit material concerning their activities for publication in the news columns of the *Aeronautical Engineering Review.*